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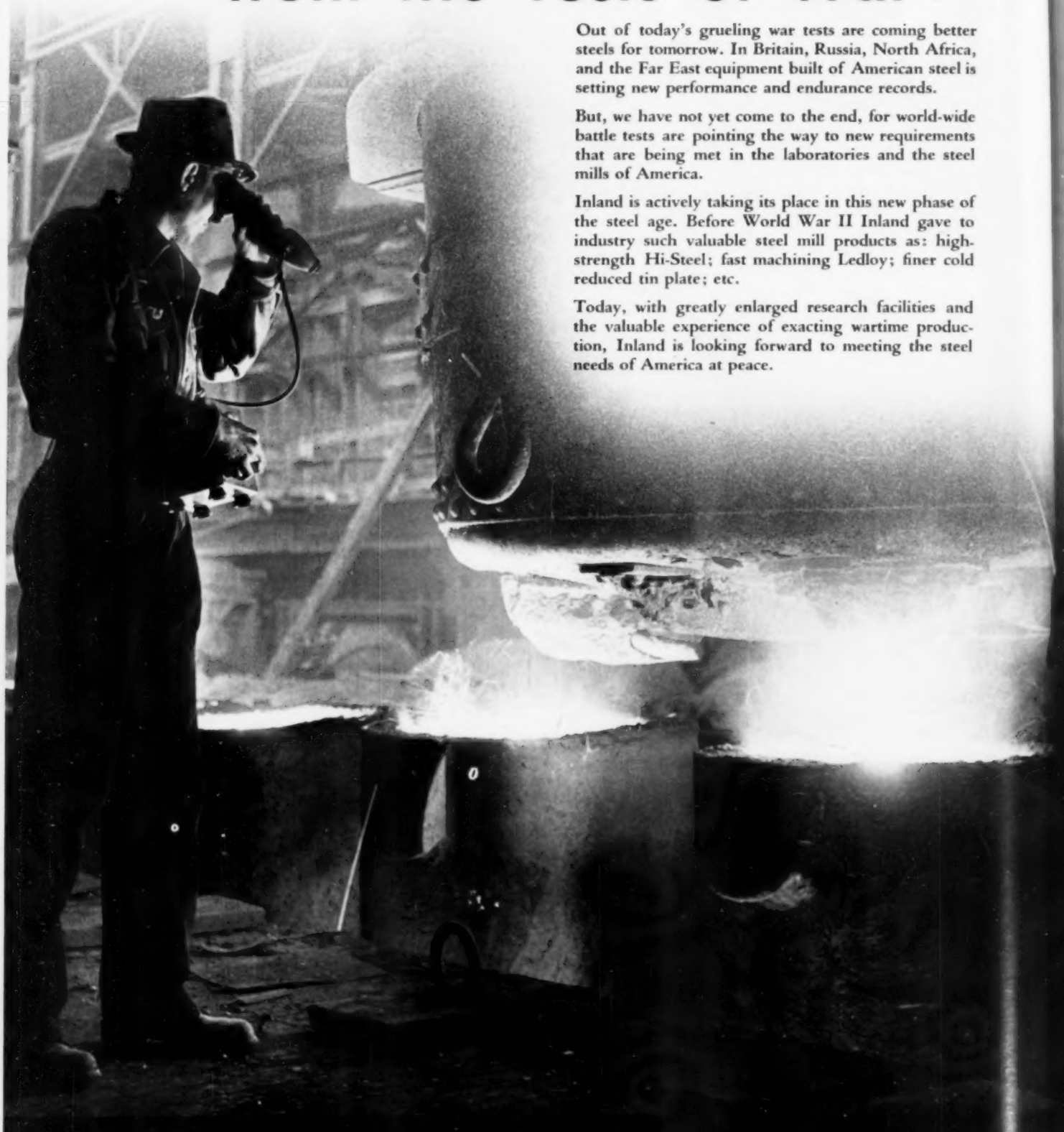
Better Steels Are Coming— from the Tests of War



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Vague Specifications for Surface Quality Hamper Aircraft Production

By C. F. Nagel, Jr.
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"VELOCITY of plane production can be greatly increased with existing plant equipment (and cost correspondingly reduced) by placing certain inspection standards on a precisely determined basis in place of the existing indefinite, variable and often opinionated anchorage."

That statement, with supporting facts, was made before the Institute of Aeronautical Sciences nearly two years ago. A definite plan of corrective action was suggested, but unfortunately nothing came of it. The hampering effect of improper restrictions is still with us; all its old baleful influences are still felt. A restatement of the case is warranted, for the American air forces need immediate action and results.

That statement, because of its brevity, may not be understood, or because of lack of supporting data may not be believed and, so, not accepted. So let us spend a little time in examining some facts. Let us not judge until those facts have been weighed.

It is the author's conviction, from more than 20 years' close contact with the production of aluminum aircraft materials, with the aircraft manufacturers' problems, and with the structural performance of aircraft in service, that many current inspection standards (if they may be dignified with the name "standards") are unnecessarily stringent; that in considerable measure they represent unsupported and questionable assumptions, opinions and deductions, rather than the product of scientifically determined data. In consequence, the aircraft industry has been paying unnecessarily a very high price in velocity of production, with no compensating benefits, and will continue to pay as long as the present situation is permitted to continue.

What is this situation with which we are here concerned? Briefly, it deals with the following three questions:

1. Which of the many properties and qualities possessed by materials, and which serve as a basis of acceptance or rejection, are actually of importance?
2. What standard of quality is actually required in each instance?
3. How shall that standard be defined in specifications and determined by inspection?

We can commence by considering almost any current specification for aluminum alloy sheet. These specifications describe the requirements as to the quality of material, how that material shall be marked and packed, the paper work involved in the transaction, and so on. We are here interested only in the matter of properties and quality of materials. This may be segregated into two categories.

(1) Those properties and qualities which, today, can be and are definitely defined, and for which definite limiting values are prescribed.

(2) Those properties and qualities for which there presently exists neither a clean-cut definition, nor definite values of measurement.

Under the first class come such matters as composition, mechanical properties and dimensions. Decision as to acceptance or rejection of material based on these matters is, consequently, not left to personal opinion or judgment. When, for example, the specification states a minimum tensile strength of 55,000 psi., material is accepted or rejected on the definite value of 55,000 lb. minimum, and not 54,000 today and 57,000 tomorrow. Furthermore, this determining value is 55,000 at the plant of the materials producer, as well as at the plant of the plane manufacturer.

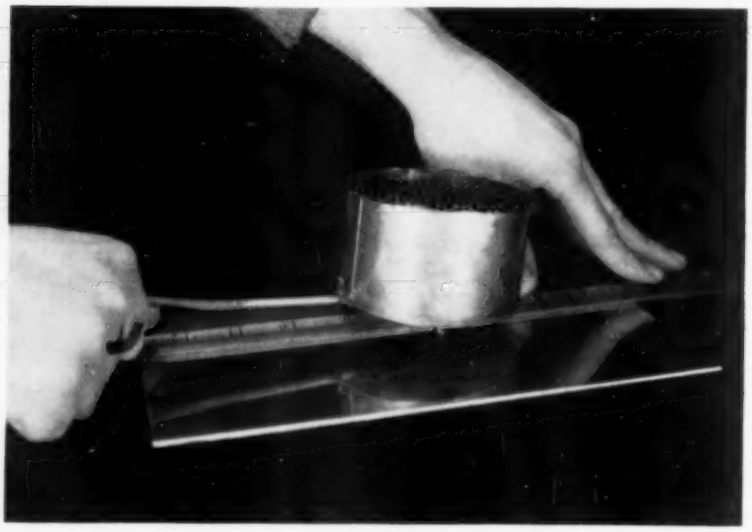

Fig. 1—Scratches Were Made With a Tool, Ground to a Triangular Point, and Weighted With Known Amount of Shot

This is not true, however, for those qualities which fall under the second category, and include such matters as flatness, straightness, metallurgical structure and surface conditions. A typical specification clause would be: "The material shall be uniform in quality and temper, clean, sound, smooth, commercially flat and free from severe buckles and other injurious defects." These adjectives are not further defined in the specifications.

Bearing in mind that specifications govern the acceptance or rejection both of the raw material and of the finished plane, and that they constitute the Bible for inspectors in various plants throughout the country, contemplate the practical application of that clause. Take for example that requirement "..free from severe buckles.." When is a buckle a severe buckle? Or consider the phrase "..commercially flat.." No piece of sheet is optically flat, but at what degree of waviness does it fail to be "commercially flat"? Next consider "..and other injurious defects.." What should be called a defect, and what should not? At what degree or stage should it be classed as injurious, and when not? It is obvious that such requirements may mean one thing to one man and another thing to another man.

Does or can Inspector Jones, at the plant of the materials producer, hold the same mental standard regarding these matters as Inspector Brown, at the aircraft plant? Encountering a lack of agreement, does Inspector Jones try to get, or succeed in getting, Inspector Brown to be "more lenient", or does Inspector Jones "tighten up" so that the material he passes will not be questioned by Inspector Brown? The normal functioning of human nature is such that the latter procedure is usually followed.

Inspectors are not the only ones involved. Most suppliers meet complaints by attempting to remove the cause, even though he may be convinced that no merit lies in the complaint. Frequently that is the easiest way out; furthermore, he does not wish to create the impression that he is unwilling to do the best possible. As a result of that one demand, the supplier raises the standard of quality not only for that customer, but for his entire production of that class of material, since it is impractical to operate a plant to several different standards of inspection. This process repeats itself time and again. The aircraft industry may have concluded, in consequence, that a more perfect material has been developed at no cost to itself. Such a conclusion is only an illusion. In the long run, while selling prices might not be increased, this increasing stringency of inspection requirements has operated against a *reduction* in selling price, but more especially has it caused an unwarranted increase in amount of plant scrap (rejects) and a general slowing down of production speeds.

Many others have a voice in shaping these "standards". The executive or production man-

age or the engineer in the aircraft plant, the Army and Navy Air forces or the civilian airline operators or flyers, each have their personal ideas as to what constitutes acceptable quality. All these people *should* have a voice in shaping standards, but when one realizes that the standards are based so largely on individual opinions and that their application rests on individual interpretations, then the confusion and waste in time and productive efficiency that must result should be very evident.

Undoubtedly one effect of this condition has been an ever heightening of standards, imperceptibly at any one time, but of considerable magnitude when spread over a few years. At this point some may say that better and ever better quality of materials is desired, especially in the aircraft industry where life and limb must be safeguarded. If existing circumstances have contributed to more perfect materials, they would continue, then those circumstances should not be altered.

Such a conclusion might seem entirely sound and convincing. But this may be one of those half-truths more misleading than a complete untruth whose falsity would be quickly recognized. The author believes that such a conclusion is entirely inadequate and sadly misleading. For one thing, it erroneously starts with such an assumption as that "gold plating" is necessary when, actually, "silver plating" might be entirely satisfactory. With an erroneous premise, all following reasoning and the final conclusions are likely to be in error.

So let us examine a few illustrative situations to determine whether certain "standards", now on a "gold plated" basis, should not be replaced by a "silver plated" or even lesser standard as wholly adequate. It is not being suggested that *any* changes be made which might have any adverse effect, to even the slightest degree, upon the highest attainable performance of the plane, nor that any chances be taken in this respect, but only that the situation be studied and then only those changes be made which such investigation proves to be correct, safe and worthwhile.

Commence with the matter of scratches in alclad 24S sheet, now a cause for rejection, not only during inspection at the sheet mill, at the aircraft factory, but also to the condition of the material in the finished plane. At the very start, remember that a big sheet at a sheet mill may be rejected for a single scratch, even though the aircraft manufacturer later cuts a large proportion of the sheet into smaller pieces. In other words, 90% of the sheet may be blameless, but none can be shipped. This causes much perfectly good material to be scrapped. Also remember that what constitutes an objectionable scratch is, at present, a very controversial matter.

To hold rejections for this cause to a reasonable figure, the sheet producer goes to great lengths in his manufacturing operations. This is not a matter of performing a particular operation that, otherwise, would not be done but, rather, of meticulous care throughout all operations in the direction of more cautious and careful handling and maintaining equipment in "jewelry" condition, all of which makes for higher cost and lower rate of production. At the aircraft plant again, extreme care must be exercised. One observes many signs: "Scratched dural is scrap dural." In one aircraft plant, every sheet is first given a coat of paint, only to be removed when the plane is completed. Throughout all operations, such special and costly procedures are employed to minimize the likelihood of scratching. The cost of these procedures and the effect upon speed of production are very substantial.

Depth of Penetration of Synthetic Scratches

Load on Scratcher	Gage of Sheet (Inches)				
	0.091 *(a)*	0.064 *(a)*	0.064 *(b)*	0.032 *(a)*	0.032 *(b)*
½ lb.	0.0007	0.0003	0.0007	0.0005	.....
1 lb.	0.0013	0.0006	0.0008	0.0006	0.0005
2 lb.	0.0014	0.0015	0.0016	0.0008	0.0016
4 lb.	0.0026	0.0019	0.0026	0.0011	0.0018
8 lb.	0.0043	0.0021	0.0032	0.0017	0.0043
12 lb.	0.0044	0.0032	0.0046	0.0028	0.0046
Average Coating	0.0046	0.0031	0.0032	0.0018	0.0017

(a): 24S-T *(b)*: 24S-O

If this care is really necessary, if minor scratches really are harmful, no one could object. Even though there exists no uniform standard as to what degree of scratching constitutes the dividing line between acceptance and rejection, let us examine some of the reasons for rejecting scratched sheet. Briefly, they are an adverse effect on tensile strength, fatigue,

workability, resistance to corrosion, or just appearance.

Are these founded on established facts, or are they merely opinion? Some recently determined data throw some light on these points.

Scratches on alclad 24S, arising in the manufacture of the sheet, result from accidentally dragging one sheet over another, or from coming in contact with some projection on the equipment. The larger the sheet and the thicker the gage, the more likelihood of scratches due to the greater weight involved. The width, depth, and length of such scratches vary, but examination has proved that the surface of high purity aluminum is never pierced.

Fig. 2 — Series of Photographs (at 100 Diameters) of Cross Sections of Scratched Sheets. White stripes represent high purity aluminum coating, darker underlying portion is a little of the 24S core. Weights on scratching tool were 0.5, 1, 2, 4, 8 and 12 lb. respectively

To make a quantitative estimate of the effect of scratches, test specimens were prepared with scratches of known dimensions. This was done with a simple device illustrated in Fig. 1. The depth of cut was controlled by the load applied to the cutting tool. In this manner a series of specimens was prepared with cutting loads ranging from 8 oz. to 12 lb. In accordance with present inspection standards (insofar as that matter can be stated today) a scratch equivalent to that made by our 2-lb. load would cause rejection.

First the specimens were cut in cross section to definitely determine the depth of the scratch. The composite photograph (Fig. 2) illustrates the depth of scratches produced with loads of ½, 1, 2, 4, 8 and 12 lb. reading from top to bottom. The scratch appears as a V in the coating. The heavier cuts produce scratches that are considerably deeper than anything occurring in the manufacture of the material. The table on page 325 shows their depth.

Tensile specimens were then cut from these various samples; tensile strength, yield strength and elongation in 2 in. were (average of four):

Scratch	Tensile	Yield	Elongation
None	62,540	42,320	20.0
12 lb.	62,660	41,920	20.5
8 lb.	62,640	42,680	20.5

Since none of the values were lowered by the scratch only the 8-lb. and 12-lb. scratched specimens were tested. Some of the broken specimens are shown in Fig. 3. The specimens were so cut from the samples that the scratches fell in different but definite locations with respect to the gage length, but in no instance did any specimen fail through the scratch.

Next, specimens were prepared to determine the effect of scratches upon the forming quality, and bent so that the scratch was located on the tension surface and parallel to it. Typical of the results are that the heat treated sheet, 0.091-in. gage, bent 180° to 4*t* radius either at a 12-lb. scratch or in a scratch-free area. The thinner gages were somewhat more susceptible; 0.064-in. sheet bent to 3*t* at a scratch-free area, but only to 4*t* radius at a 12-lb. scratch. It should be borne in mind that these synthetic scratches nearly penetrated the high purity aluminum coating on the 0.091-in. sheet and actually did so on the 0.064-in. sample, whereas scratches produced in manufacturing never penetrate the coating, being very much more shallow. It is a safe prediction from these tests that the great majority of the

material currently rejected for scratches will be found to form just as satisfactorily at locations of a scratch as at adjacent scratch-free locations.

Resistance to corrosion is another quality at issue. Voluminous data already exist proving that, even at sheared edges where the core is necessarily exposed, the core is electrolytically protected by the adjacent high purity aluminum. No one is much concerned about the sheared edges, so any fear concerning the possible corrosion at a scratch is entirely unwarranted.

There is left the matter of fatigue. No laboratory test data are available. However, service experience is to the effect that fatigue failures in alclad 24S sheet are conspicuous by their absence. To this, should be added the statement that, within a relatively few weeks after a plane is put into service, scratches are produced with a greater frequency and degree than would ever be permitted in the raw material or in the plane on acceptance.

Frequently when conditions such as slight scratches or other surface imperfections are under discussion the statement is made that such defects are stress raisers, and from the viewpoint of fatigue should not be tolerated. No one disputes the fact that a notch is a stress raiser and lowers fatigue endurance, but the error lies in the indiscriminate application of that principle. Upon acceptance of the initial premise, it is too casually applied throughout the plane. With this in mind, refer to the paper, "Fatigue Failures Affecting Transport Aircraft," by H. E. Hoven of American Airlines, presented January 28, 1942 at the annual meeting of the Institute of Aeronautical Sciences. This paper lists types of airplane parts in which at least 20 fatigue failures or fatigue cracks have been noted in its fleet during the past three years. Of those 20 items, only two involve the air frame. Of these two, one was corrected by substitution of a heavier extruded angle (indicating that failure was not a matter of inspection standards but one of design) and the other was corrected by cutting the shape to a larger radius — also not a matter of inspection standards but again one of design. In other words, fatigue failures of parts of the air frame in that fleet were conspicuous by their absence, yet undoubtedly many parts of the stressed skin had been "badly" scratched during servicing or operating.

The above data are presented not with the contention that they establish that scratches should not be considered a basis of rejection, but only to support the contention that the present "standard" of inspection is of doubtful validity. Development of data showing conclusively the effect of scratches upon various properties should not be difficult. A more difficult phase would be to find a practical means of measuring this condition by the inspector, but existence of a difficulty should not be an argument against tackling a problem.

Another illustrative situation is the ban against "pick-up" on 17S-T and 24S-T extruded shapes. Pick-up is a slight roughening of the surface, almost too slight to be detected with one's finger, and results from metal tending to stick a trifle to the surface of the extrusion die. An attempt is made in Fig. 4 to show its appearance. The first and fourth specimens from the top show pick-up; it is indicated by the little dark specks. The other three specimens are free from pick-up. Presence of pick-up constitutes a cause of rejection, and this is again covered by the above quoted typical specification clause for quality of surface.

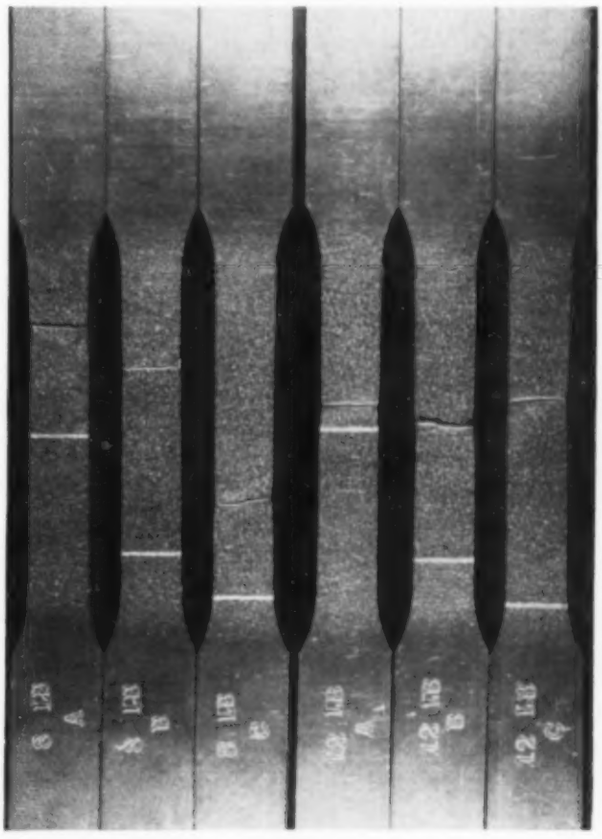

Fig. 3 — Alclad 24S-T, 0.091-In. Gage, Scratched and Tested in Tension. Eight-pound scratches at left; 12-lb. at right. No failure in any test even with these deep scratches

The apparent objection to this condition is that it may promote corrosion. Tests made in the Aluminum Co. of America's research laboratories do not substantiate such a contention, for Fig. 4 also shows these same specimens after they have been exposed 48 hr. to a solution of sodium chloride and hydrogen peroxide in alternate immersion. Note that those specimens which contained pick-up have corroded to no greater extent than the others. Mechanical properties of these specimens were determined both before and after exposure to this corroding medium, and these tests confirmed the visual conclusion that the presence of pick-up had no effect upon resistance to corrosion. Also, these tests showed that pick-up did not harm the static mechanical properties.

Admittedly, neither the volume of present existing data, nor its scope, would be considered sufficient by all to immediately change inspection standards with respect to this condition, but certainly it is adequate to throw suspicion upon the validity of present vague inspection standards for surface quality, and that is all that the author here intends. Meeting the current requirements represents either high inspection losses at the producers' plant, or reduces the rate of extrusion (this reduces the degree of pick-up); either situation operates toward low production from each unit of expensive, massive machinery.

Still another instance involves so-called "die marks" on extruded shapes. "Die marks" are difficult to describe. They consist either of longitudinal ridges resulting from the steel die having become slightly scratched, or of longitudinal depressions resulting from particles of aluminum adhering to the die.

Presence of die marks constitutes a basis of rejection. Actually, *all* extruded sections contain die marks, although some are so minute as to require a magnifying glass to reveal them. No stated limiting value is in existence today defining what is passable and what is not. This is again a matter of personal judgment and an undefined though variable standard reached by inspectors in the process of time.

The reasons for objecting to die marks are also rather uncertain. There exists the suspicion that that condition might adversely affect resistance to corrosion; very likely some might believe that the strength properties are

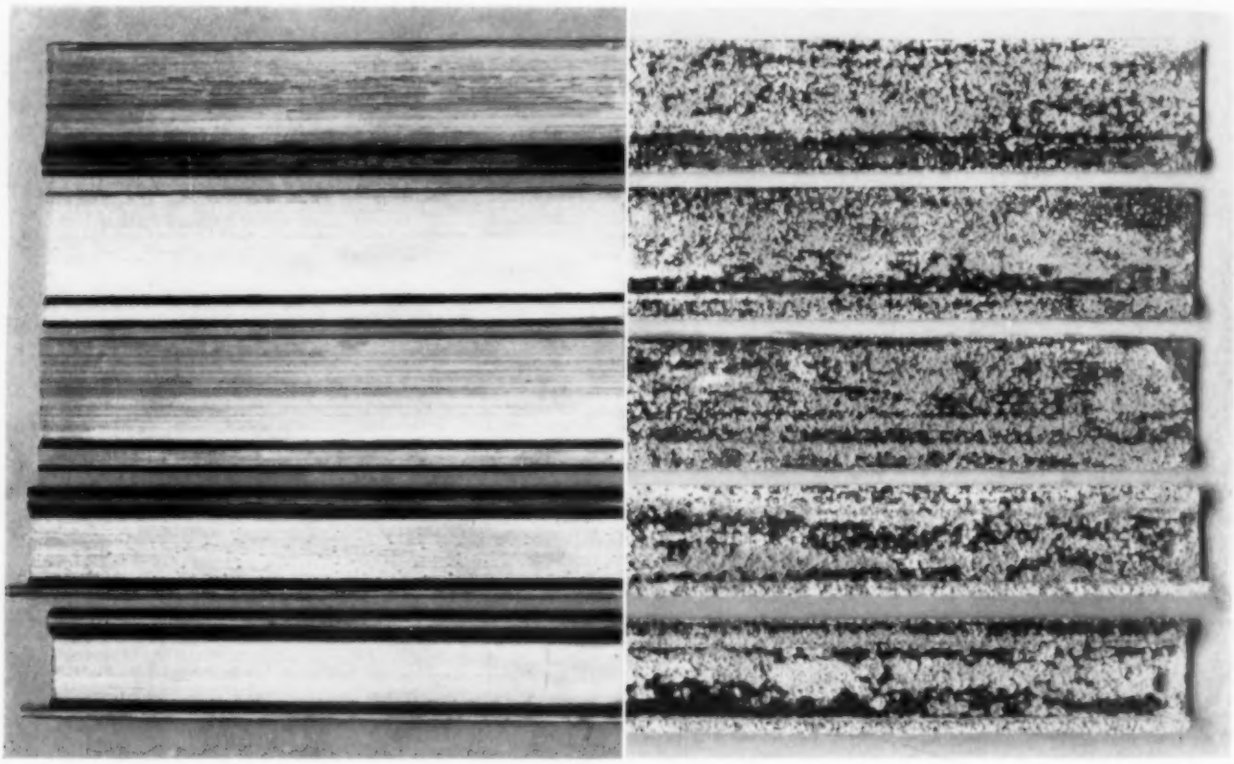

Fig. 4 — Reading from top, No. 1, 2 and 3 are the same shape; No. 1 has "pick-up" (speckled roughness). No. 4 and 5 are the same shape; No. 4 has "pick-up". After 48 hr. alternate immersion in NaCl plus H_2O_2 specimens with "pick-up" are no more corroded than smoother surfaces

adversely affected, or perhaps the ability of the material to form or stand up under fatigue.

In Fig. 5 an attempt has been made to show what a die mark is. The top two specimens on the left, which were cut from a thin extruded section, are free from die marks. The bottom two on the left each contain one die mark, pointed out by the arrows. These specimens were exposed to a sodium chloride hydrogen peroxide solution by alternate immersion. The same specimens after one hour of this are shown at the right of Fig. 5. There is about as much corrosion on the specimens free of the die mark as on the others, and corrosion is no greater along the line of the mark. This contradicts any contention that corrosion will commence sooner along a die mark.

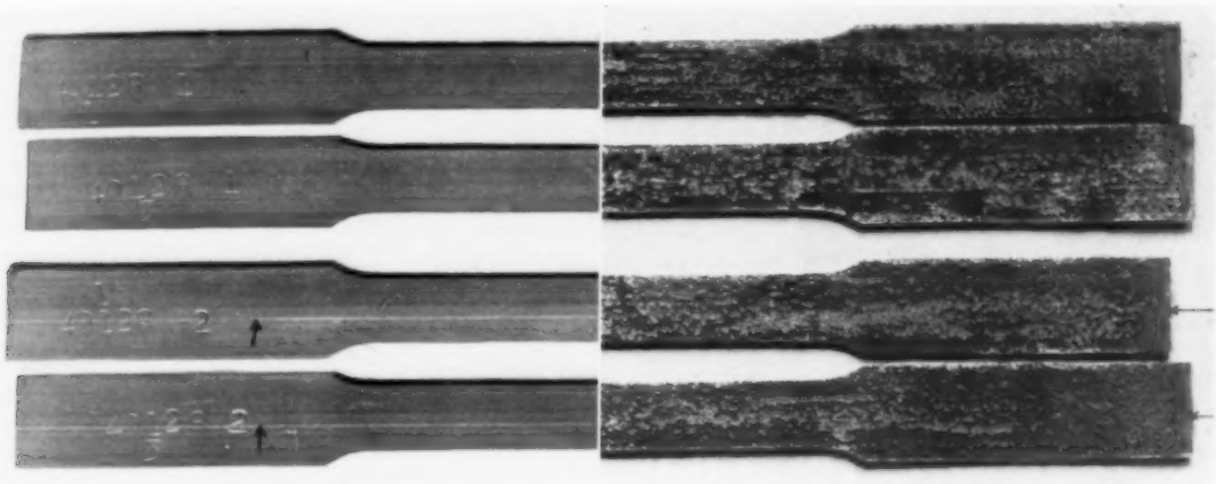

Fig. 5—Four Specimens Were Cut From a Thin Extruded Shape, Two of Which Had Severe "Die Marks". Alternate immersion in NaCl plus H_2O_2 for one hour failed to show selective corrosion along the die marks

It would not be expected that such a small depression, running longitudinally to the length of the specimen, would show any effects on the static mechanical properties and this was found to be the case. It might be thought that the *transverse* mechanical properties would be adversely affected. No tests on this point are available at the moment, either *pro* or *con*. However, in examining quite a few specimens, taken from rejected material, the deepest die mark found had a depth of only 0.00062 in., which represented only about 1% of the thickness of the section.

As in the previous examples, it is not contended that this small amount of data merits anything more than to raise the question as to the validity of the present inspection standards, but the author does believe that it is sufficient for that.

Many other matters of quality or properties used as a basis of acceptance or rejection of material might be cited, for which there exists no definite method of measurement or where the standard of inspection is of questionable validity. These other matters are small blisters, nicks in extruded shapes and tubing, and straightness of extruded sections.

Both static and fatigue tests have demonstrated that nicks and various surface imperfections in tubing are not nearly as damaging as rivet holes, whether filled with a rivet or not (and tubing is invariably joined by rivets or bolts). When failure occurs it always takes place through the hole and never at the location of the minor surface imperfection. Yet the cost of producing tubing so that the surface will pass current inspection standards is very high.

Extruded sections are badly warped and twisted by the heat treating operation. No mechanical equipment thus far developed has succeeded in straightening certain sections to presently required standards; the final straightening is a hand job and is extremely costly in time and labor. Tolerances as to straightness do exist. Some inspectors will lay the section on a table when examining it for straightness, so its weight will tend to straighten it. Others lay the section on its side so that any slight spring will show to its maximum.

Maximum straightness attainable is desirable in shapes functioning *(Cont. on page 428)*

Boron—A New Vitamin for Steel and Cast Iron

By Norman F. Tisdale
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Pittsburgh, Pa.

THE TIME for replacing some of the usual alloying elements in steel with more available materials has arrived. During the present emergency, industry must choose available substitutes in place of its ordinary alloys; even the armed services will have to economize on their consumption of strategic metals. Boron is one of the many such substitutes which have been suggested. Therefore, considerable attention has been focused on the effects of boron when added to cast iron and steel.

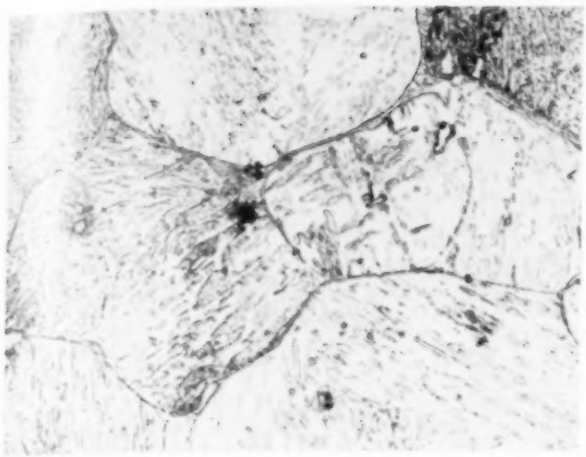
The problem of conservation of alloying elements in steel has been considered by both governmental agencies and the steel industry. However, many problems remain to be solved. Certain modifications of the physical and chemical specifications of the steel are in order for many applications.

A review of the literature concerning the use of boron is found to be somewhat confusing, since the quantities previously employed were excessive. Formerly, additions as great as 4.0% were used, but present day experiments by the writer and cooperating investigators have indicated that the element should be used *very* sparingly. Perhaps the habit of thinking in tonnage terms has hampered the metallurgist in his consideration of an element whose beneficial effects are paramount in amounts below 0.003%!

Two years ago a research fellowship was established in the Metallurgical Engineering Dept. of the University of Pittsburgh by the Molybdenum Corp. of America for the purpose of studying the effects of boron in steel and cast iron. It was found early in this investigation that excessive amounts of boron (even 0.03%) caused hot shortness.

This property is usually attributed to the formation of an envelope of insoluble material around the grain boundaries. The presence of iron sulphide in the grain boundaries of steel is the classical example of this effect. Boron, when used in excessive amounts, is no exception to this rule, because of the precipitation of films of a constituent, thought to be a solid solution of iron carbide and iron boride. This phenomenon is illustrated in the accompanying photo-micrograph at 500 diameters, which shows the structure of a red-short steel containing 0.03% boron, quenched from 1800° F. The grain boundary envelopes indicate the insolubility of the new constituent in austenite at that temperature.

As long as the grains are not completely surrounded by this embrittling constituent, no red shortness is encountered. In some steels, as much as 0.008% boron may be present without the formation of this closed envelope, but less than 0.003% is generally recommended and is being used commercially by a number of steel companies at present. In this small quantity boron has been found to be beneficial. There is some indication that by such additions



Microstructure of a Hot-Short Boron Steel (0.03% Boron), Water Quenched From 1800° F. Electrolytic etch, magnified 500 diameters

the tensile strength is increased without noticeably changing the reduction of area or percentage elongation.

Increased physical properties account for the use of boron in crankshafts and other automobile parts. It has been used successfully in hot rolled spring steels of large cross-section to increase hardness penetration (hardenability). The need for conservation of chromium has led to the development of new manganese-molybdenum-boron steels in which the major alloying elements are kept on the low side of their normally specified ranges, thus resulting in a desired economy.

In cast irons, 0.02 to 0.10% boron is used effectively with beneficial results, since large amounts of iron carbide (Fe_3C) are present to hold the iron boride in solid solution. This element inhibits graphitization, thus tending to produce white fractures in which the carbon is present in the combined form. Boron, therefore, acts as an agent for the control of depth of chill in iron rolls, and also increases surface hardness. Previous investigators have shown that the complex carbide (Fe_3C-Fe_2B) exists when boron is added to cast iron and is responsible for the above effects. See particularly the work by P. G. Bastein and L. Guillet, Jr., in *Carnegie Scholarship Memoirs* for 1938, abstracted in Metal Progress, April 1939, page 396.

New developments in the method of adding boron to iron and steel are also responsible for the commercial success of this element. A recently developed ferro-boron containing 10 to 14% boron has resulted in higher efficiency and greater recovery than was formerly effected when borates or boron ore were used as addition agents. Since a few thousandths of one per cent of boron will produce very marked changes in the physical properties of the product, efficiency and accuracy of control of the boron additions are essential. This low melting point ferro-boron dissolves readily in the steel, and the boron acts as a ferrite strengthener and an agent in the formation of complex carbides.

Research is now in progress for the use of this element in plain carbon as well as alloy steels and irons. Technical data on these experiments may be expected in the near future.

Three Months From Order to Delivery. Baldwin Locomotive Works completes first freight engine on large lease-lend order, designed, engineered and built in record time

Standardized Methods for Determining Austenitic Grain Size of Steel

By The Steel Standardization Group

Bethlehem Steel Co.
Carnegie-Illinois Steel Corp.
Chrysler Corp.
Great Lakes Steel Corp.
Pittsburgh Crucible Steel Co.
Republic Steel Corp.
The Timken Roller Bearing Co.
Steel & Tube Division

AS NOTED by the Editor of METAL PROGRESS in his "Critical Points" for November 1941, the "Steel Standardization Group" has been holding monthly meetings for over ten years in an effort to standardize test methods, so that any laboratory in any of the plants of the participating group could check the results of any other. Its work had nothing to do with specifications, quality of material, or productive operations. However it was well known that many details of common testing procedures were left to the judgment of the operator, and the cumulative effect of normal variations was too great for satisfactory check tests.

Among the several test methods scrutinized in detail were the methods for determining the austenitic grain size of steel. Austenitic grain size has long been known to have a measurable influence on machinability and on hardenability. Standardized methods described below for the determination of grain size were developed by The Steel Standardization Group during the period 1937 to 1939. The need for such methods became apparent during the course of the committee's work, when it was found that wide disagreements were existing among the nine cooperating laboratories working on samples of the same steel.

First to be standardized was the McQuaid-Ehn method because of its widespread use at that time, and because it provided a means of studying the grain size of steels in the core and transition zone as well as in the hyper-eutectoid case. The "oxidation method" was standardized later because it provided a simple and shorter method of testing and introduced no change of composition (as does carburizing).

McQuaid-Ehn Method

Preparation of Sample—For samples from standard $1\frac{1}{8}$-in. bar, see Fig. 2, opposite.

For other sizes and shapes, the following types of samples shall apply:

(a) Round bars: If 1 in. in diameter or larger, see Fig. 2; if smaller than 1 in. in diameter, see Fig. 3.

(b) Square bars: If 1 in. or larger, see Fig. 4; if less than 1 in., see Fig. 5.

(c) Rectangular sections: If the flat face is 1 in. or over, see Fig. 6; if the flat face is under 1 in., see Fig. 7, which also applies to all flat spring sections.

Microscopic examination shall be made in the areas marked *A*, as representative of the case of the freshly cut surface; and in the areas *B*, as representative of the case of the scaled surface or mill bar surface of the stock.

Extreme care shall be taken in the cutting of samples for carburizing. Experience shows that cutting samples on the high speed cut-off wheel

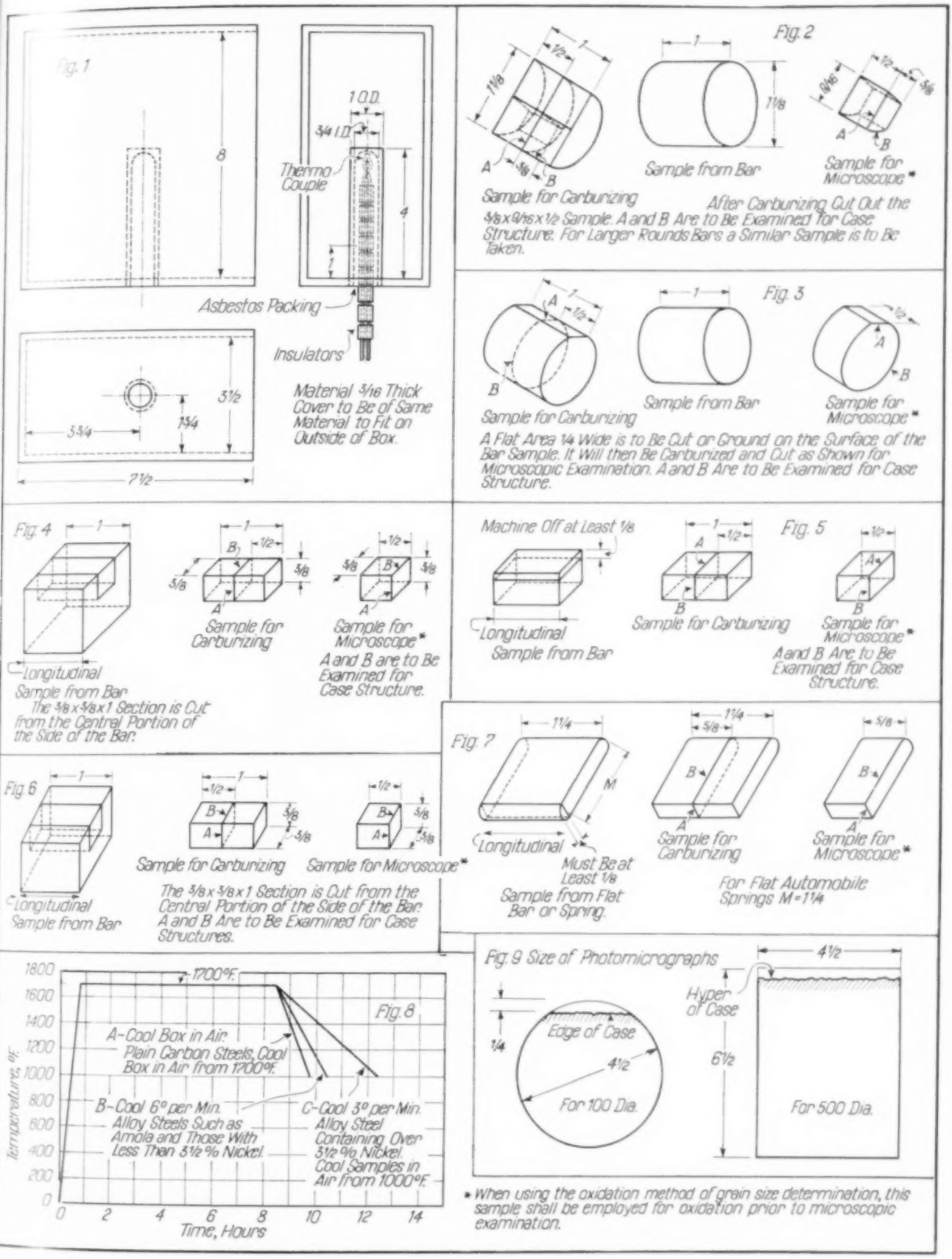


Fig. 1
8
1 O.D.
3/4 I.D.
Thermo Couple
4
1
Asbestos Packing
Insulators
3 1/2
3 3/4
1 3/4
7 1/2
Material 3/16 Thick Cover to Be of Same Material to Fit on Outside of Box.
Fig. 2
1 1/8
1/2
1
A
3/8
B
Sample for Carburizing
Sample from Bar
9/16
Sample for Microscope *
After Carburizing Cut Out the 3/8 x 9/16 x 1/2 Sample. A and B Are to Be Examined for Case Structure. For Larger Rounds Bars a Similar Sample is to Be Taken.
Fig. 3
Sample for Carburizing
Sample from Bar
Sample for Microscope *
A Flat Area 1/4 Wide is to Be Cut or Ground on the Surface of the Bar Sample. It Will then Be Carburized and Cut as Shown for Microscopic Examination. A and B Are to Be Examined for Case Structure.
Fig. 4
Longitudinal Sample from Bar
The 3/8 x 3/8 x 1 Section is Cut from the Central Portion of the Side of the Bar.
Sample for Carburizing
Sample for Microscope *
A and B are to Be Examined for Case Structure.
Machine Off at Least 1/8
Longitudinal Sample from Bar
Fig. 5
Sample for Carburizing
Sample for Microscope *
A and B Are to Be Examined for Case Structure.
Fig. 6
Longitudinal Sample from Bar
Sample for Carburizing
Sample for Microscope *
The 3/8 x 3/8 x 1 Section is Cut from the Central Portion of the Side of the Bar. A and B Are to Be Examined for Case Structures.
Fig. 7
1 1/4
5/8
M
Longitudinal
Must Be at Least 1/8
Sample from Flat Bar or Spring.
Sample for Carburizing
Sample for Microscope *
For Flat Automobile Springs M = 1 1/4
Fig. 8
1700°F.
A-Cool Box in Air. Plain Carbon Steels, Cool Box in Air from 1700°F.
B-Cool 6° per Min. Alloy Steels Such as Amola and Those With Less Than 3 1/2 % Nickel.
C-Cool 3° per Min. Alloy Steel Containing Over 3 1/2 % Nickel. Cool Samples in Air from 1000°F.
Temperature, °F.
Time, Hours
Fig. 9 Size of Photomicrographs
4 1/2
Hyper of Case
1/4
Edge of Case
4 1/2
For 100 Dia.
6 1/2
For 500 Dia.
* When using the oxidation method of grain size determination, this sample shall be employed for oxidation prior to microscopic examination.

Details of Standardized Samples for Determining Austenitic Grain Size in Steel, as Agreed Upon by The Steel Standardization Group. Also carburizing box, heating cycle and size of micros are noted

may interfere with the absorption of carbon. Therefore, surfaces which have been cut on a high speed wheel and are later to be examined under the microscope shall be ground before carburizing.

Carburizing Compound — The carburizing compound shall be made with hardwood charcoal, using the size known to the trade as "No. 6".

Screen Analysis		Composition of Finished Compound	
100% through	6 mesh	$BaCO_3$	10%
30% on	8 mesh	$CaCO_3$	5%
69% on	14 mesh	Na_2CO_3	2%
		Oil binder	12%
		Hardwood charcoal	Balance

The oil binder used is Pennsylvania grade motor oil conforming to S.A.E. No. 20.

Small, air-tight packaging is recommended to maintain an even moisture content (4% max.).

Carburizing Box — The carburizing box shall be according to Fig. 1, page 333, which also indicates the thermocouple tube and the position of the inside thermocouple.

Packing of Samples — At least 1 in. of compound shall be placed between the samples and the top, bottom, and sides of the box, and there shall be a minimum distance of 1 in. separating any two samples. This space shall be filled with compound. Only new compound should be used in packing samples.

Carburizing Procedure — The furnace temperature shall be 1700° F. when the box is charged and shall be so regulated that the temperature of the thermocouple in the box shall reach 1700° F. in 40 to 50 min. This temperature shall then be maintained for exactly 8 hr. Cooling shall then be immediately started and maintained at the rate shown on Fig. 8, page 333, depending upon the type of steel used.

Heating, holding, and cooling curves of the box couple shall be shown with report.

Etching — After preparation (polishing) of the sample, it shall be etched for examination of the hyper-eutectoid zone in cold sodium picrate solution about 40 sec. with a current of six volts (specimen the anode), the etchant made-up in accordance with Formula 22, page 724 of the 1939 Edition American Society for Metals' Handbook.* (The use of boiling sodium picrate for 5 to 10 min. is optional.)

For the hypo-eutectoid zone and core, 2% nital shall be used.

Grain Size Measurement — Grain size shall be measured by the chart in American Society for Testing Materials specification E19-39T.† Magnifications for grain size shall be 100 diameters.

Examination of grain size shall be made on both the rolled surface ("B" in the figures) and cut surface ("A" in the figures on page 333). If the variation is not over three numbers on both surfaces, one record only will be necessary. In the event that variation is over three numbers, the amount of variation, together with location, shall be reported.

Photomicrographs of the grain size at 100 diameters shall be 4½ in. in diameter. The edge of the case shall be ¼ in. from the outside edge of the print. In mounting the photomicrographs, the outside edge of the sample shall be toward the top of the page.

The hyper-eutectoid zones shall be recorded for grain size and recorded as the "Hyper-Eutectoid Zone".

In special circumstances, where it is believed that the standard size photomicrographs are not desirable or where areas at 500 magnifications are to be recorded, any size of print may be used. The preferred size of print for 500 diameters (4½ by 6½ in.) and that for 100 diameters are illustrated in Fig. 9, page 333.

Oxidation Method

Preparation of Sample — Proceed as described above under McQuaid-Ehn method, with the exception that no cut is made after oxidation, since surfaces to be examined are exposed during the entire test. Grind and polish these surfaces, finishing with 400 alundum on canvas.

Oxidation — In the case of steels not to be carburized, insert the sample, polished surface up, into a furnace heated to 1600° F. Remove after one hour and quench in cold water or brine.

Steels intended for carburizing are inserted into a furnace heated to 1700° F., removed at the end of six hours and quenched in cold water or brine solution. During the first five hours, oxidation should be checked by placing a cover of small volume over the test pieces. The cover is removed for the last hour.

Polishing — The quenched test piece is then polished with 600 alundum and finished with levigated alumina, avoiding the removal of excessive amounts of the oxidized surface.

Etching — Etch in 15% hydrochloric acid in ethyl alcohol from 2 to 10 min. Fresh etchant is recommended.

Grain Size Measurement — Follow procedure outlined under the McQuaid-Ehn method above, considering oxidized surface and hyper-eutectoid zone to be equivalent for this purpose.

*Solution of 2 g. picric acid and 25 g. sodium hydroxide in enough water to make 100 ml. (Easily prepared by dissolving 25 g. NaOH in 60 ml. water; add 2 g. picric acid and heat until dissolved; then make up to 100 ml. with distilled water.) Mixture should always be alkaline to litmus.

†See Data Sheet, Metal Progress, October 1941 Reference Issue, page 452.

A chapter from a forthcoming book on Powder Metallurgy, edited by John Wulff

Dies for Fabrication of Porous Bearings

By A. J. Langhammer
and Milton F. Smith
Amplex Division, Chrysler Corp.
Detroit, Mich.

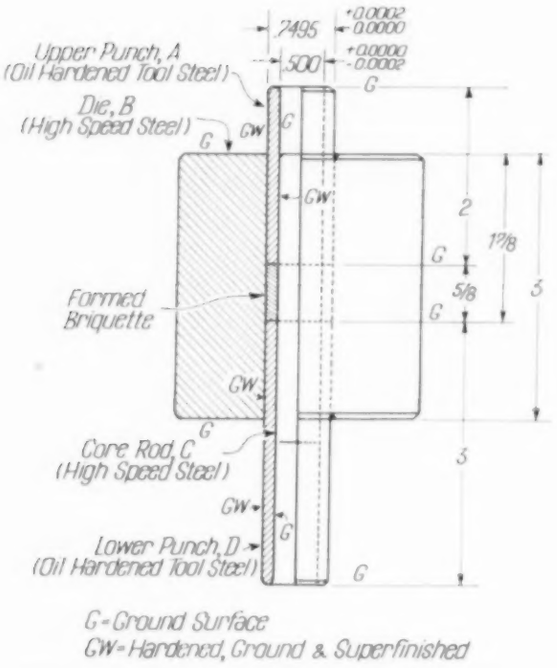
TWO steps in the fabrication of porous bearings require the use of dies, namely the briquetting or compacting process, and the sizing or finishing process. In the former operation, the loose metal powder is compressed under high pressures. The grains are distorted as they are brought into intimate contact, and are packed so closely together that they interlock and form a briquette ready to be heat treated. Like sand, these particles tend to move in only one direction. In the second operation of sizing or finishing, the heat treated or sintered part is now formed to precision tolerances by a unique process of sizing which replaces the older machining methods of turning, boring, facing, and reaming. It gives the bearing surfaces a fine burnished finish, accurate as to outside diameter, inside diameter, and length. In both operations, hand or non-production dies may be made before production tools are released, if old dies are not available to carry out the preliminary experimental work.

A simple set of briquetting tools has two stationary parts and two movable parts. The first figure shows a hand die set-up and the other two a set of production tools. Stationary parts are *B*, the die, which forms the outside diameter of the bearing, and *C*, the core rod, which forms the inside diameter. The movable parts are *A*, the upper punch, which transmits pressure and forms the upper end of the briquette and *D* the lower punch, which forms the lower end of the bearing and ejects it from the die after compression.

At the start of the production cycle the bottom punch is in the down position, providing a well. The loading shoe first moves over the well and fills it with powder. When the loading shoe is clear of the die cavity, the upper punch is brought down into the well and compresses the briquette. As the upper punch is removed from the well, the top of the lower punch is raised flush with the face of the die, ejecting the formed briquette and then returning to the lower position. The loading shoe brushes the formed briquette aside and at the same time reloads the die. The briquette expands somewhat, so it cannot drop back in the well.

A set of sizing tools, such as illustrated in the last drawing, has one stationary part and two movable parts. The stationary part is the

Parts up to 7½ In. Diameter Pressed of 3 Parts 99% Iron Powder (Low in Carbon and Silica) and 1 Part Copper Powder. Courtesy Chrysler Corp.

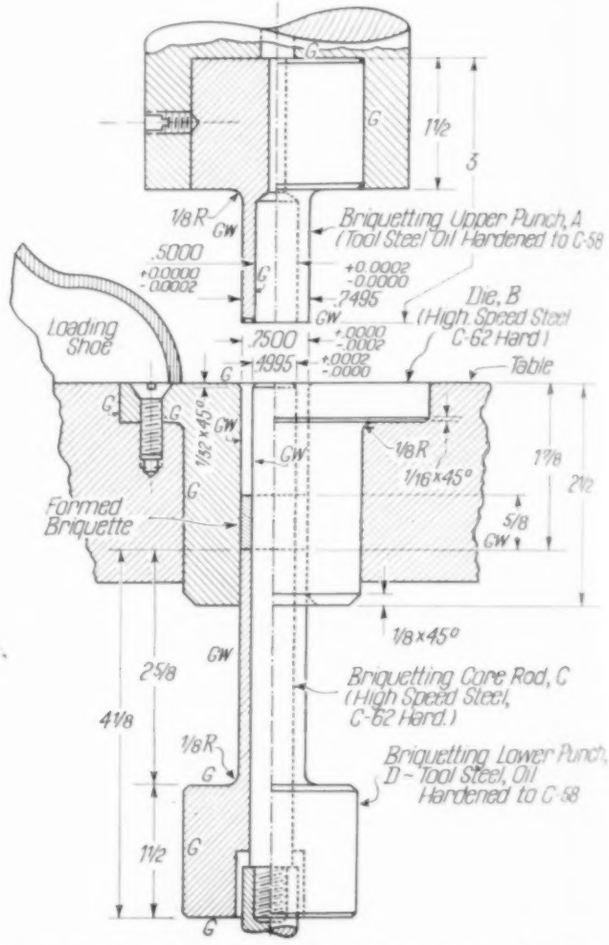


Drawing of Experimental or Hand Die for Plain Cylindrical Bearing. Ratio of die fill to briquette volume is roughly 3 to 1

die, which controls the outside diameter of the bearing. The movable parts are *A*, the punch, which sizes the inside diameter of the bearing, and *D*, the "knockout", which ejects the bearing from the die. In the sizing tool the pressed and sintered piece is first placed on the die and then forced into it by the punch which, while descending, sizes the bore or inside diameter of the bearing. The bearing is finally ejected from the die with the sizing knockout, *D*.

Certain calculations are always involved in the design of briquetting tools. The amount of stock which is to be left on the outside and inside diameter of the piece for sizing and also its length must be determined. Other necessary measurements are the dimensional changes of the bearing in heat treatment. Thus to achieve the desired outside diameter of 1.000 in. we must add 0.010 in. for sizing stock, and 0.010 in. for shrinkage during sintering. Under these conditions the inside diameter of the briquetting die would be 1.020 in. The length of the briquetting die depends on the finished length of the piece and the density of the powder. If the briquette is to have a density of 6.0 g. per cc., and the powder's apparent density is 3.0 g. per cc., then the height of powder in the well should be twice the length of the briquette. As the only adjustment for length is the well length of the dies, this can be calculated from the ratio of density, powder to briquette. Normally this ratio approximates 3 to 1.

The choice of steel for the die parts may be made on the basis of cost per bearing, provided a production of more than 500 pieces is required. Cost of the steel is usually but a small proportion of the cost of the finished die, but we may take the following exaggerated examples:



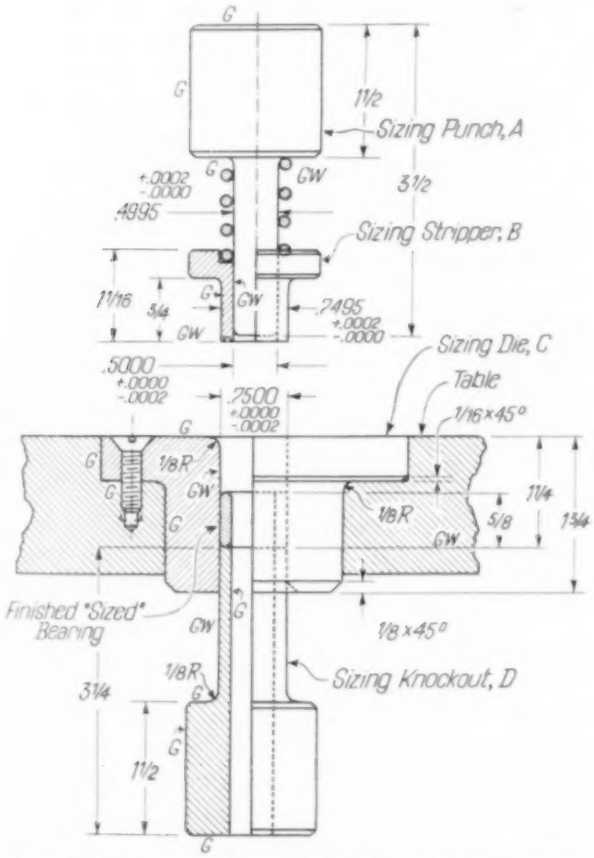
Production Dies for Plain Cylindrical Bearing. Ratio of die fill to briquette volume is roughly 3 to 1. G means hardened and ground surface. GW means hardened, ground and superfinished surface

Grade Steel	Cost of Steel in Die	Life of Die (Pieces)	Die Cost (Metal Only) Per Piece
A	$30.00	50,000	$0.00060
B	25.00	20,000	0.00125
C	15.00	7,000	0.00214

Thus, "A" grade steel is most economical for a run of 50,000 pieces, if it costs no more to make into a tool than the others. For certain parts, the use of steels with high wear or abrasion resistance is good practice. Parts of the dies which have

thin sections, or are subject to movement, are generally made of steels chosen for their toughness. High speed steel, because of its wearing qualities, is selected for the briquetting die and core rod, as well as for the sizing die and punch. Oil hardening toolsteel may be used to advantage for the upper and lower briquetting punches and for the sizing knockout. Unusual care should be exercised to eliminate weak sections, to provide liberal radii, and to follow other elements of good practice.

For fabricating simple parts, such as the cylindrical bearing illustrated, any number of different standard presses may be employed, particularly if the part is relatively short. Mechanically activated presses are generally used for parts requiring low tonnages, and hydraulic units for high tonnages. Economy usually dictates a mechanical press for small parts and a hydraulic press for large parts, even though the latter is slower in action, less adaptable, and often a more costly machine.



Sizing Tools for Plain Cylindrical Bearing. Sizing punch A and sizing die C are high speed steel, hardened to Rockwell C-62. Stripper B and knockout D are oil quenched toolsteel C-58 hard. Working surfaces marked G are hardened and ground; GW are superfinished in addition

Heavy Alloy

By G. H. S. Price, S. V. Williams and G. J. O. Garrard

Extracts from "Heavy Alloy — Its Production, Properties and Uses", Metal Industry (London), Dec. 5, 1941, p. 354; Dec. 12, p. 372; Dec. 19, p. 394.

WHILE INTEREST of recent years has centered in the production of light alloys, there are certain purposes for which a heavy metal or alloy is required and thus "G.E.C. Heavy Alloy" was developed by the British General Electric Co., Ltd.

In the search for a heavy metal, tungsten with density of 19.3 g. per cc. seemed to be the best springboard. Production of large pieces of pure tungsten is not practical but with the addition of nickel and copper, alloys were obtained showing a density of 16.5 to 17 g. per cc. and a tensile strength comparable with that of a good quality steel. Since the expression "heavy metal" is reserved for alloys having a density of 16 g. per cc. or higher, only alloys containing 80% or more tungsten were investigated. When an alloy of intermediate density is required molybdenum can be substituted for all or part of the tungsten in heavy alloy. In this way has been prepared a complete range of sintered powders with densities ranging from about 10 up to 17 g. per cc.

Satisfactory alloy can be made from a mixture of tungsten powder with 10% nickel powder, but the introduction of copper permits a lower sintering temperature with a marked improvement in the properties. In sintering, the molten copper "wets" the tungsten particles and cements them together, whereas the nickel tends to segregate.

Requisite quantities of tungsten, nickel and copper powders, suitably fine, are thoroughly mixed together in the dry state. A small quantity of a solution of wax in benzol is then added for binder, and the mixing continued until all the solvent has evaporated. The binder makes it possible to press coherent masses at much lower pressures than would otherwise be necessary; a pressure of from 5 to 10 tons per sq.in. is generally quite satisfactory.

The pressed pieces are slowly heated to approximately 1825° F. in a reducing atmosphere in a muffle furnace. The heating cycle must be slow if disruption of the pieces is to be avoided. During this pre-firing *(Continued on page 406)*

Critical Points

By The Editor

TO NEW YORK, and attended an afternoon's discussion on "Ores, Metals and the War" at the Mining Engineers' annual convention. Organized by ROBERT MCCONNELL, formerly in charge of conservation and substitution problems for OPM, it was conducted by many of his former associates, men who are in a position to know what the present situation is. Puzzled, however, by the discrepancy between the general statements made at the meeting and others released by the War Production Board in recent weeks. Truth to tell, many generalities are indulged in, with little actual data slipping past the censor . . . . . Take chromium, for instance. The general impression thrown out was that interrupted imports would be replaced by Montana sources, now producing at the rate of 80,000 tons of 40% Cr per year, with some 170,000 tons more capacity coming in by year's end, a total of 250,000 tons. How this can *replace* our missing imports, at least double that total, is understandable only by the restriction of metal and refractory ore to the manufacture of steel and alloys with A-1 priority, and a corresponding elimination of many non-war uses of chemical ore. In other words, we're on starvation rations . . . . . It was stated that in January the control board released only two-thirds of the chromium available. Thus the government was doing a little hoarding of its own, defensible enough in the light of the following facts drawn from the report of the National Academy of Sciences' Advisory Committee on Metals and Minerals, and released for publication by the War Production Board:

One year's supply of chromite

"As of Sept. 19, 1941. A significant point, which possibly will not be indicated till the end of the year, is that during the next 60 to 65 days we expect to clean up all the surplus stocks of chromite in the world, and thereafter we shall be on a current production basis. Except for increased production in the United States and Alaska, we cannot expect to increase our foreign supply appreciably regardless of the shipping situation. . . . . It would be too optimistic to anticipate that domestic production could be increased beyond about 200,000 gross tons of ore per year. Imported ores have been arriving to date at about the rate at which they are being consumed. It is quite evident, however, that should the importation of ore be curtailed, the stocks together with the ore that can be produced in this hemisphere would not last for more than about a year."

Discouraging additional facts: The Cuban ore deposits are good for firebrick only; our principal present source of metallurgical ore is far, far over seas.

TORN between belief and doubt on hearing ANDREW LEITH, technical consultant to War Production Board, say that the manganese shortage is more potential than actual. His statement that there is more metal on hand now than a year ago and that the reserves are still growing still does not alter the fact that nearly all of this manganese was imported. A true believer would I be, especially of a contemporaneous news release by HAROLD ICKES about "a domestic manganese war program of sufficient scope to free American steel and alloy production from its present reliance on foreign sources", but on reading further find that a laboratory process, described only six weeks before by the Bureau of Mines for the beneficiation of the 18% Mn nodules from Chamberlain, South Dakota, has been enlarged into one of three plants which "could produce a minimum of 312,175 tons of manganese metal equivalent annually, and would require an investment of $24,000,000". The horrid suspicion even enters that the Honorable Secretary's political eye was not closed when he selected "12 plants in 10 locations in 8 states" . . . . . Wonderful would it be if by 1942's end we would have 10 workable deposits developed and producing. Meanwhile we may accept LEITH's more circumstantial statement that reserves on hand, plus imports from Cuba, Brazil, Chile and Mexico, plus production in the

Manganese said to be sufficient

stake (Montana and the Appalachians), will permit us to make the anticipated 83 million and so on until we can develop new deposits and actually become self-sufficient in manganese. . . . . No one questions our enormous resources in low-grade ore; the pressing problem is to find ways to get the manganese out of it. Hasten the day! We need the manganese not only for ordinary steel, but *extra* manganese in millions of tons of shell steel and the manganese-molybdenum steels that are to replace a lot of nickel and chromium steels. Also high manganese steel makes excellent "tin hats"; don't let us get into a position where we can't make superior tank armor because we can't spare the manganese!

VASTLY encouraged, however, at this same Mining Engineers' Symposium on War Metals, by PHILIP WILSON's report of expansion in American magnesium, needed immediately for aircraft landing wheels and crank cases, flares and incendiaries. Since he also is technical consultant to the War Production Board, his figures were not thoughtlessly published, and so can be quoted without risk of censorship and with the hope they will make Adolph, Benito, and the Son of Heaven nervous. The whole story is too long to compress into a short item like this; in fact, the notes which follow this are merely a summary of WILSON's talk. Suffice it here to give the Editor's interpretation of the data on plant capacities and completion dates . . . . . Dow Chemical Co.'s 1938 production of 4,500,000 lb. has been expanded to present production rate of 55,000,000 lb. per year. Here's a 12-fold expansion already. But that's only a start. By 1942's end we will have the following producing capacity: From electrolytic plants (Dow cell) 230,000,000 lb.; from electrolytic plants (M.E.L. cell) 112,000,000; by ferrosilicon reduction, 100,000,000 lb.; by carbo-thermal reduction, 35,000,000; by pilot plants on other processes, 13,000,000 lb.; total capacity 490,000,000 lb., well over 100 times American pre-war production . . . . . Since these plants will be ready at various times during the rest of this year, it is better to estimate the actual metal to be made. Assuming 90% plant efficiency by end of 1942 and 100% operations by the end of 1943, we have the following:

A lot of magnesium for Tokyo

1938	4,500,000 lb.
1939	9,000,000
1940	15,000,000
1941	40,000,000
1942	150,000,000
1943	460,000,000 plus

All this from the pre-Pearl Harbor construction program. Mr. Davis said, "A very much greater amount of magnesium must now be provided; the figures are huge but the censor will not permit their disclosure." One might guess that at the very least a 1943 building program equal to 1942 will be undertaken. On this basis the production of magnesium in 1943 will be boosted up to something on the order of 600,000,000 lb. and plant for producing at the rate of 800,000,000 lb. should be in existence . . . . Oh, ye British, Russians, Chinese and Dutch, hang on until we can get this thing a-going!

Increasing the Magnesium Output 100-Fold

SOME 25 years ago Dow Chemical Co. turned its attention to waste magnesium chloride in salt-well brines treated for other chemicals; its successful process for making magnesium metal, described by JOHN A. GANN before the Institute of Metals Division, A.I.M.E. (and reported in METAL PROGRESS for April 1932) was a triumph of dogged determination and engineering resourcefulness. In the intervening years Dow was the sole producer, despite a "ten million dollar failure" by the American Magnesium Corp. to work out a scheme similar to the commercial process for electrolyzing aluminum oxide in a molten fluoride bath.

Notes on a talk ★ by
Philip D. Wilson
Technical Consultant,
W.P.B., Washington

In the quarter-century American production of magnesium gradually climbed to about 4,500,000 lb. (yearly average for 1934-1938). [Some accusations have been made that the amount was purposely held low by nefarious agreements. In the EDITOR's view it was much

★At the annual meeting, American Institute of Mining and Metallurgical Engineers, New York, Feb. 11, 1942.

Top Operating Floor of Re-Distillation Building, Permanente Magnesium Plant. The cylinders, whose domed tops only can be seen, are about 5 ft. in diameter and 25 ft. tall. Wide World Photos

more likely due to the intensive promotion of aluminum, its competitive light metal, and to the fact that, as a byproduct, its economical output was limited by the demand for the other and principal products of the brines.]

By 1940 the Dow company could see that the increased demand for metal was far too much for even its expanded Michigan operations (about 9,000,000 lb. per year) so it built on the Texas Gulf Coast and had in operation early that fall a plant of 18,000,000 lb. capacity which performed the legendary feat of extracting metal from sea water. Since then the capacity of that plant has been doubled, so we are getting today 36,000,000 lb. of magnesium yearly from the Gulf, and the end is not yet, for a neighboring 72,000,000-lb. plant will start operations early this summer. This 25-fold expansion over 1938 American consumption by a single company within three years is sufficiently notable in itself to warrant highest praise.

Some remarks about the raw material are in order. The Michigan brines have about one part magnesium metal per hundred, and their chemical treatment consists of evaporating most of the water, crystallizing out the other salts (mostly of sodium and calcium), purifying the remaining magnesium chloride, evaporating five of the six molecules of water-of-crystallization, and electrolyzing the dried salt in a mixed sodium-magnesium chloride melt. The products are magnesium metal, and a usable mixture of hydrochloric acid and chlorine gas. Sea water, which contains only about one part magnesium per thousand, but is inexhaustible and accessible, is run over hydrated lime made from oyster shells, the magnesium precipitated as hydrate and converted to $MgCl_2$ with recirculating chlorine gas from the electrolytic cells. Some new wells have recently been drilled in Michigan into a rock horizon saturated with brine carrying 10% $MgCl_2$ — a rich enough "ore" to be shipped to any inland point where a block of surplus power is available.

No less than three large chemical works are preparing to recover chloride from waste liquors, and reduce it to metal in the Dow cell. The brines available are to be enriched by magnesium from calcined dolomite (limestone carrying more or less magnesium carbonate). Briefly the process is to burn the dolomite in a lime kiln, hydrate it, take magnesium and calcium into solution by reacting with chloride brines, precipitate the calcium as carbonate by the CO_2 in the kiln gases, and then recover the $MgCl_2$ from the solution as from a natural brine. Using these processes, Diamond Alkali Co. will be producing 36,000,000 lb. per year in northern Ohio by summer time, Union Potash Co. 24,000,000 lb. per year in central Texas also by

mid-summer, and Mathieson Alkali Works 36,000,000 lb. by autumn (and another 18,000,000 early in 1943) in a plant in Louisiana. The latter's electrolytic cell has been modified so it will produce no hydrochloric acid but only chlorine gas, also an essential war material.

Here, then, is a total of 231,000,000 lb. annual capacity by plants using the Dow electrolytic cell or a modification, and working on an unlimited supply of natural brines and sea water. Present production rate is 55,000,000 lb. per year (almost equal to the entire world's in 1939, the last year of reliable statistics). From these plants alone we should be getting magnesium at the rate of 90,000,000 lb. by early summer (equal to the guessed-at world production of 1940), 135,000,000 by midsummer, 180,000,000 by fall, and 210,000,000 by new year's.

But — and this is the good news — this is little more than half we will have by January 1943, because of other plants using other methods!

First should be mentioned the achievements of the plant at Permanente. It reduces magnesium oxide (a sea water byproduct of Westvaco Chlorine Products' plant nearby) with carbon in an electric arc furnace, "shock cools" the vapor emerging at 3800° F. by a blast of natural gas, thus chilling metal particles so fast there is no time for oxidation by the reverse reaction. The resulting fume (magnesium metal, some oxide, and carbon dust) is collected in protective gas atmosphere, mixed with oil to a dough and re-distilled at 1400° F. in tall cylindrical alloy retorts; their upper parts form condensers, and they are removed bodily and used as pots in which to remelt the solid crystals of 99.95% metal. The used gases and petroleum vapors go to an adjoining cement plant for fuel.

In Mr. Wilson's words, the 24,000,000-lb. plant at Permanente "is having its share of troubles, but it produced its first high quality metal last October, and is likely to contribute substantially toward the program". The original plant is now being doubled. Likewise other firms are building pilot plants for using this carbo-thermal reduction; molten lead is being used by Dow Chemical Co. for fume coolant, and oil by Ford Motor Co.

The largest magnesium plant in the world is yet to be described. Basic Magnesium Ltd. is building near Boulder Dam ten replicas of the Magnesium Elektron, Ltd.'s English plant. This plant also uses an electrolytic process, but instead of fused chlorides for electrolyte, as in the Dow cell, the so-called "M.E.L. cell" utilizes a fused pure magnesite. Likewise a feed of anhydrous $MgCl_2$ is required, difficult to prepare except by dry methods. Raw material comes from a vast deposit of unusually pure magnesium carbonate and hydrate minerals in southwestern Nevada; the rock is quarried, concentrated by unique flotation technique developed by the U. S. Bureau of Mines, calcined, and the oxide trucked across the state to the reduction plant. Here it is briquetted with Canadian peat moss for porosity and converted to anhydrous magnesium chloride by chlorination with gas from the electrolytic cells. By year's end this one enterprise alone will be making at the annual rate of 112,000,000 lb. of magnesium, more than the entire world did in 1940.

Still there are other processes a-building! One selected by the National Academy of Sciences involves the reaction between calcined dolomite and powdered ferrosilicon at 2050° F. in a vacuum; the magnesium vaporizes and is condensed as high purity metal in the water-cooled end of the retort. Three years of preliminary experimentation on this process by Dominion Magnesium Co., Union Carbide & Carbon Corp., and Ford Motor Co. has perfected the details, and plants are being erected by them as well as by American Metal Co., National Lead Co., and New England Lime Co. They have the advantage of being quickly built wherever there is available power, and will be producing another 100,000,000 lb. within six months. The process will require pound for pound of 75% ferrosilicon, but this is easily made in a simple electric furnace from sand, coke and steel scrap. Likewise, it will need plenty of nickel-chromium heat resisting retorts.

Since the ores are widespread and limitless, the bottleneck may be power, especially when these plans are superimposed on a 2-billion lb. per year aluminum program. Fortunate indeed we are to have the huge hydro-electric plants in the west. Ferrosilicon plants are being scattered around the edges of eastern industrial centers, where there is an apparent surplus of civilian power, already available. One horsepower of energy working for a year will produce only 500 lb. of magnesium. Again to quote Mr. Wilson, "The total electrolytic portion of the original pre-Pearl Harbor program is scheduled to use over 500,000 kilowatts of connected power for 334,000,000 lb. of metal per year." A big figure, but even so, only a fraction of what we can get from Grand Coulee's power house.

National Emergency Alternates for Alloy Steels

Extracts from a report by
Committee on Alternates for Alloy Steels
American Iron & Steel Institute

SHORTAGE of nickel led the American Iron & Steel Institute, during the summer of 1941, to convene a committee to study the possible substitutes (for civilian use) for the conventional nickel steels of both carburizing and deep hardening types. [Its ensuing report was summarized in METAL PROGRESS for September 1941.] Some of the recommended substitutes carried less nickel; others contained no nickel but sizable amounts of chromium, with or without vanadium or molybdenum. Carbon-molybdenum steels also were mentioned, with which the steel and automotive industry was quite familiar.

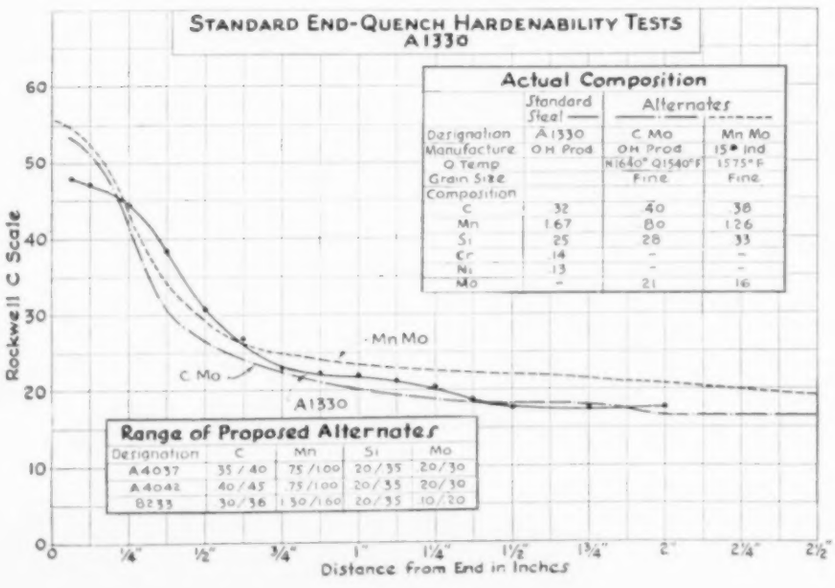
On Sept. 16, 1941, the Office of Production Management sharply restricted deliveries of alloy steel, defining "alloy iron or steel" as iron or steel containing more than 1.65% manganese, 0.60% silicon, or 0.60% copper, or any intentionally added amount of other alloying element. This priority order made it necessary to develop alternate steels for those types most seriously affected. Therefore, upon the request of the Office of Production Management to American Iron and Steel Institute, an informal committee of 29 metallurgists selected from the Technical Committees of the Institute, the Society of Automotive Engineers, Inc., and other interested manufacturers held several conferences and performed certain experimental work for the purpose of studying possible alternates.

What follows is quoted verbatim from their report, published by the Institute as "Contributions to the Metallurgy of Steel; No. 5. Possible Alternates for Nickel, Chromium, and Chromium-Nickel Constructional Alloy Steels."

As a further means of conserving alloying elements in order to make them available for essential military uses certain arbitrary restricted limits were placed upon individual elements, when used in alternate steels, by the Office of Production Management on December 20, 1941, as follows:

"Manganese in excess of 1.65%; copper in excess of 0.60%; chromium in excess of 0.60%; molybdenum in excess of 0.60%; nickel in excess of 0.60%; cobalt, tungsten or vanadium in any amount specified or known to have been added to obtain a desired alloying effect."

The study of possible alternates was confined to constructional alloy steels of



the types comprised by the S.A.E. and A.I.S.I. list. The alternate steels do not embrace the following types of steel: Low alloy, high tensile steels which are furnished as flat rolled products and which require no heat treatment; stainless steels or irons such as the high chromium or chromium-nickel types; medium chromium (2 to 10% chromium) steels which sometimes contain other elements and which are used to resist scaling at elevated temperatures; or any class of toolsteel.

Certain considerations on the various alloys were borne in mind:

Manganese. As a means of conserving low-carbon ferromanganese a limit of 1.00% manganese was set for steels in which the carbon content does not exceed 0.25%. For higher carbon steels a limit of 1.65% manganese was set.

Silicon. Because of the reported uncertainty of a continuous supply of ferrosilicon containing a consistent percentage of silicon, and the steel industry's limited experience in the use of steels containing a relatively high amount, the Committee has adhered to the general practice of specifying a silicon content of about 0.20 to 0.35%, except in the case of the 9200 series. [See the Data Sheet, page 345, for the revised numberings and chemical compositions.]

Nickel. Small quantities of nickel are recoverable from recurrent alloy steel scrap turnover. By combining this incidental or recoverable nickel with small quantities of pure nickel or of other elements a saving in the over-all use of all such elements will be made. Therefore a maximum nickel content of 0.60% is recommended for alternate steels.

Chromium. Because of the possibilities of conservation inherent in the use of small quantities of several alloying elements, as stated above, rather than a large amount of a single element, a maximum chromium content of 0.60% is recommended for alternate steels.

Vanadium is completely restricted under Priority Order M-23-a.

Titanium. No specific limits are recommended, and it is not recommended for use in alternate steels because reduction facilities and priority preferences for special uses may make its general use impossible.

Zirconium. Same considerations apply as for titanium.

Tungsten. This element is completely restricted under Priority Order M-3 and M-3-a dated March 26, 1941, and subsequent modifications.

Molybdenum. A maximum of 0.60% is recommended except for steels which must have special creep characteristics.

Addition Agents. Special alloying compounds called "addition agents" or "reaction alloys", which contain combinations of boron, silicon, titanium, vanadium and zirconium have been used in some types of steel with rather remarkable results. However, their use is not recommended in the series of alternate steels presented herein because experience with them and knowledge as to their effects on all grades of steel is limited. Moreover, a recommendation for general use might complicate problems of availability. These addition alloys are so numerous in type that their introduction into a work of this sort would tend to confuse the effort to minimize the number of grades of steel and complicate the problem of mill supplies and inventories.

National Emergency Alternates

The alternates presented in the table on page 344 embrace new carbon-molybdenum, manganese-molybdenum, low chromium-molybdenum and low nickel-chromium-molybdenum steels. The latter series of steels can be used to effect savings of chromium or nickel (or both) in cases where such a combination is required because of the properties desired, and to reduce the number and type of other possible alternates which might be suggested. The alternate steels have all been identified within the 8000 series.

In all basic openhearth steels, series NE 8000, silicon shall be within the limits 0.20 to 0.35%, phosphorus and sulphur shall each be 0.040% max. Small quantities of certain elements may be found in alloy steel which are not specified or required. These elements are to be considered as incidental and acceptable to the following maximum percentages: Copper 0.25; nickel 0.25; chromium 0.20; molybdenum 0.06%.

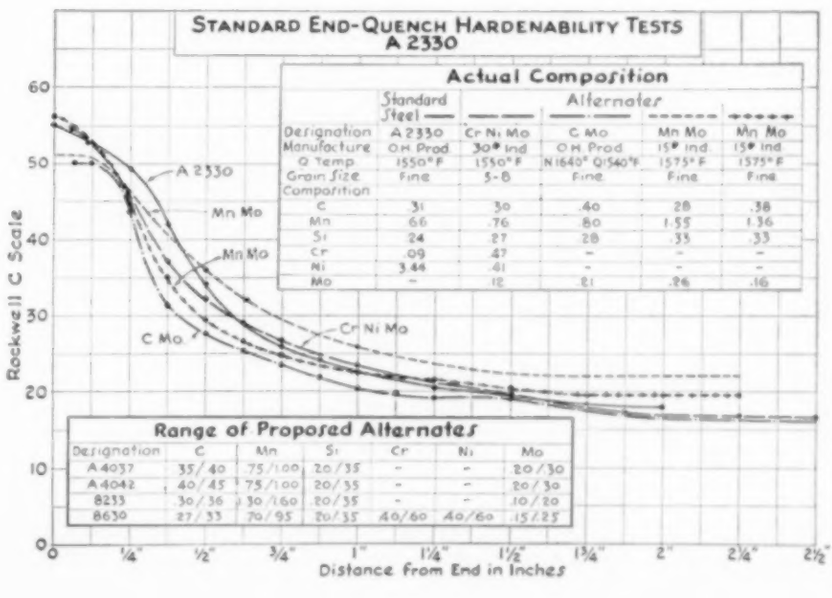


Table I — National Emergency Alternate Steels*

Designation	Chemical Composition				
	C	Mn	Mo	Ni	Cr
NE 8024	0.22-0.28	1.00-1.30	0.10-0.20	....	....
NE 8124	0.22-0.28	1.30-1.60	0.25-0.35	....	....
NE 8233	0.30-0.36	1.30-1.60	0.10-0.20	....	....
NE 8245	0.42-0.49	1.30-1.60	0.10-0.20	....	....
NE 8339	0.35-0.42	1.30-1.60	0.20-0.30	....	....
NE 8442	0.38-0.45	1.30-1.60	0.30-0.40	....	....
NE 8447	0.43-0.50	1.30-1.60	0.30-0.40	....	....
NE 8547	0.43-0.50	1.30-1.60	0.40-0.60	....	....
NE 8620	0.18-0.23	0.70-0.95	0.15-0.25	0.40-0.60	0.40-0.60
NE 8630	0.27-0.33	0.70-0.95	0.15-0.25	0.40-0.60	0.40-0.60
NE 8724	0.22-0.28	0.70-0.95	0.20-0.30	0.40-0.60	0.40-0.60
NE 8739	0.35-0.42	0.75-1.00	0.20-0.30	0.40-0.60	0.40-0.60
NE 8744	0.40-0.47	0.75-1.00	0.20-0.30	0.40-0.60	0.40-0.60
NE 8749	0.45-0.52	0.75-1.00	0.20-0.30	0.40-0.60	0.40-0.60
NE 8817	0.15-0.20	0.70-0.95	0.30-0.40	0.40-0.60	0.40-0.60
NE 8949	0.45-0.52	1.00-1.30	0.30-0.40	0.40-0.60	0.40-0.60

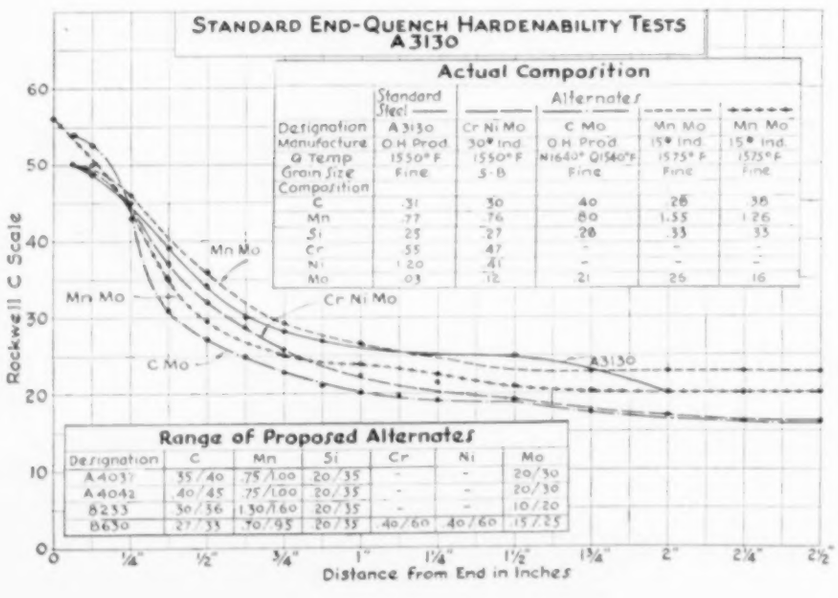
*To these should be added the old steels A 4027, A 4037, A 4063 and A 4068.

Carburizing Grades

The most commonly used standard carburizing steels and possible alternates therefor are as shown in Table II.

Table II — Carburizing Steels

Standard Series Designation	Alternate Steels			
	C-Mo	Cr-Mo	Mn-Mo	Cr-Ni-Mo
A 1320	A 4027	....	NE 8024	....
A 2317	A 4027	A 4125	NE 8024	NE 8620
A 2515	A 4027	....	....	NE 8817
A 3120	A 4027	A 4125	NE 8024	NE 8620
A 4119	A 4027	....	NE 8024	....
A 4120	A 4027	A 4125	NE 8024	....
A 4320	....	....	NE 8124	NE 8724
A 4620	A 4027	A 4125	NE 8024	NE 8620
A 4820	....	....	NE 8124	NE 8724
A 5120	A 4027	A 4125	NE 8024	....
A 6120	A 4027	A 4125	NE 8024	NE 8620


STANDARD END-QUENCH HARDENABILITY TESTS
A 3130
Actual Composition
Standard Steel
Alternates
Designation A 3130 Cr Ni Mo C Mo Mn Mo Mn Mo
Manufacture O.H. Prod. 30* Ind. O.H. Prod. 15* Ind. 15* Ind.
Q Temp 1550° F M1640° Q1540°F 1575° F. 1575° F
Grain Size Fine 5-8 Fine Fine Fine
Composition
C .31 .30 .40 .28 .38
Mn .77 .76 .80 1.55 1.26
Si .25 .27 .28 .33 .33
Cr .55 .47 - - -
Ni 1.20 .41 - - -
Mo .03 .12 .21 .26 .16
Mn Mo
Mn Mo
Cr Ni Mo
C Mo
A3130
Rockwell C Scale
Distance From End in Inches
Range of Proposed Alternates
Designation C Mn Si Cr Ni Mo
A 4037 .35/.40 .75/1.00 .20/.35 - - .20/.30
A 4042 .40/.45 .75/1.00 .20/.35 - - .20/.30
8233 .30/.36 1.30/1.60 .20/.35 - - .10/.20
8630 .27/.33 .70/.95 .20/.35 .40/.60 .40/.60 .15/.25

[Comparative physical properties shown in Table III, page 347, are scaled from numerous charts in the pamphlet. For the tests, 1-in. bars were "pseudo-carburized" or heated 8 hr. to 1680° F. and quenched in oil, or reheated to the quenching temperature tabulated, so chosen to give the maximum Izod value of the carburized sample. All samples were oil quenched, drawn 1 hr. at 400° F. Tensile and Izod specimens were cut from the core. The carburized Izod specimen was 0.394-in. square, with 0.040-in. case.]

In addition to armament purposes the principal uses of the carburizing grades are:

1300 Series for automotive differential ring gears and pinions.

2300 Series for automotive gears, knuckle pins, shafts and collars.

2500 Series for aircraft engine crankshafts, and truck, bus and tractor transmission and differential gears.

3100 Series for tractor transmission gears, oil well drilling cutters and reamers and anti-friction bearings.

3300 Series for aircraft engine piston pins and gears, and for heavy duty truck gears, bearings and pneumatic tools.

4100 Series for automotive differential ring and pinion gears and tractor transmission or differential gears, oil well drilling cutters and reamers, anti-friction bearings, and general purpose pins and shafts.

4300 Series for bus and truck transmission and differential gears.

4600 Series for automobile and tractor transmission and differential gears, anti-friction bearing parts, oil well drilling cutters and general purpose pins and shafts; also in large quantities in the aircraft industry for gears, pins and similar applications.

4800 Series for truck, bus and tractor transmission and differential gears and shafts, and oil well rotary cutters.

5100 Series for automotive and tractor gears and pinions, pins and shafts.

6100 Series for automotive truck and bus differential gears, shafts and pins.

Semi-Thorough Hardening Grades

The currently used standard grades of semi-thorough hardening steels consist of both water hardening and oil hardening grades. They are generally used in tensile strength ranges of from 100,000 to 150,000 psi. and in Brinell hardness number ranges of 200 to 300.

Standard Steel Compositions

Jointly Issued, January 21, 1942, by American Iron & Steel Institute and Society of Automotive Engineers

Openhearth Alloy and Electric Furnace Carbon and Alloy Steels

(Blooms, Billets, Slabs, Bars and Hot Rolled Strip)

Code	C	Mn	P Max.*	S Max.*	Si*	Ni	Cr	Mo
E 1320	0.18–0.23	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....
E 1330	0.28–0.33	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....
E 1335	0.33–0.38	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....
A 1340	0.38–0.43	1.60–1.90	0.040	0.040	0.20–0.35	.....	.....	.....
A 2317	0.15–0.20	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....
A 2330	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....
A 2335	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....
A 2340	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....
A 2345	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	.....	.....
E 2512	0.09–0.14	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	.....	.....
A 2515	0.12–0.17	0.40–0.60	0.040	0.040	0.20–0.35	4.75–5.25	.....	.....
E 2517	0.15–0.20	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	.....	.....
A 3045	0.43–0.48	0.75–0.95	0.040	0.040	0.20–0.35	0.60–0.80	0.60–0.80	.....
A 3115	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....
A 3120	0.17–0.22	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....
A 3130	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....
A 3135	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....
A 3140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	.....
A 3141	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....
A 3145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....
A 3150	0.48–0.53	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	.....
A 3240	0.38–0.45	0.40–0.60	0.040	0.040	0.20–0.35	1.65–2.00	0.90–1.20	.....
E 3310	0.08–0.13	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	.....
E 3316	0.14–0.19	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	.....
A 4023	0.20–0.25	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4024	0.20–0.25	0.70–0.90	0.040	(a)	0.20–0.35	.....	.....	0.20–0.30
A 4027	0.25–0.30	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4028	0.25–0.30	0.70–0.90	0.040	(a)	0.20–0.35	.....	.....	0.20–0.30
A 4032	0.30–0.35	0.70–0.90	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4037	0.35–0.40	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4042	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4047	0.45–0.50	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4063	0.60–0.67	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
A 4068	0.64–0.72	0.75–1.00	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
NE 8024	0.22–0.28	1.00–1.30	0.040	0.040	0.20–0.35	.....	.....	0.10–0.20
NE 8124	0.22–0.28	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.25–0.35
NE 8233	0.30–0.36	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.10–0.20
NE 8245	0.42–0.49	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.10–0.20
NE 8339	0.35–0.42	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.20–0.30
NE 8442	0.38–0.45	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.30–0.40
NE 8447	0.43–0.50	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.30–0.40
NE 8547	0.43–0.50	1.30–1.60	0.040	0.040	0.20–0.35	.....	.....	0.40–0.60
A 4119	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.40–0.60	0.20–0.30
A 4120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.60–0.80	0.20–0.30
A 4125	0.23–0.28	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.40–0.60	0.20–0.30
A 4130	0.28–0.33	0.40–0.60	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
E 4132	0.30–0.35	0.40–0.60	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.18–0.25
A 4134	0.32–0.37	0.40–0.60	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
E 4135	0.33–0.38	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.18–0.25
A 4137	0.35–0.40	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
E 4137	0.35–0.40	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.18–0.25
A 4140	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
A 4142	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
A 4143	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.30–0.40
A 4145	0.43–0.48	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
A 4150	0.46–0.53	0.75–1.00	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15–0.25
E 4150	0.48–0.53	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.20–0.27
NE 8620	0.18–0.23	0.70–0.95	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.15–0.25
NE 8630	0.27–0.33	0.70–0.95	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.15–0.25
NE 8724	0.22–0.28	0.70–0.95	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.20–0.30
NE 8739	0.35–0.42	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.20–0.30
NE 8744	0.40–0.47	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.20–0.30
NE 8749	0.45–0.52	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.20–0.30
NE 8817	0.15–0.20	0.70–0.95	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.30–0.40
NE 8949	0.45–0.52	1.00–1.30	0.040	0.040	0.20–0.35	0.40–0.60	0.40–0.60	0.30–0.40
A 4317	0.15–0.20	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30
A 4320	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30
A 4337	0.35–0.40	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	0.60–0.80	0.30–0.40
E 4337	0.35–0.40	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	0.70–0.90	0.23–0.30
A 4340	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30
E 4342	0.40–0.45	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	0.70–0.90	0.23–0.30
A 4608	0.06–0.11	0.40 max.	0.040	0.040	0.25 max.	1.40–1.75	.....	0.15–0.25
A 4615	0.13–0.18	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30
E 4617	0.15–0.20	0.45–0.65	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27
A 4620	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30
E 4620	0.17–0.22	0.45–0.60	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27
A 4621	0.18–0.23	0.70–0.90	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30
A 4640	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30
E 4640	0.38–0.43	0.60–0.80	0.025	0.025	0.20–0.35	1.65–2.00	.....	0.20–0.27
A 4645	0.43–0.48	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	.....	0.20–0.30
A 4815	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	.....	0.20–0.30
A 4820	0.18–0.23	0.50–0.70	0.040	0.040	0.20–0.35	3.25–3.75	.....	0.20–0.30
A 5045	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.55–0.75	.....
A 5120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....
A 5130	0.28–0.33	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	.....
A 5140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....
A 5145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....
A 5150	0.48–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	.....
A 5152	0.45–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.90–1.20	.....
E 52095	0.90–1.00	0.30–0.50†	0.025	0.025	0.20–0.35	.....	0.45–0.65	.....
E 52098	0.90–1.05	0.30–0.50†	0.025	0.025	0.20–0.35	.....	1.00–1.25	.....
E 52099	0.90–1.05	0.30–0.50†	0.025	0.025	0.20–0.35	.....	1.30–1.65	.....
E 52100	0.95–1.10	0.30–0.50†	0.025	0.025	0.20–0.35	.....	1.20–1.50	.....
E 52101	0.95–1.10	0.30–0.50†	0.025	0.025	0.20–0.35	.....	1.30–1.65	.....
E 52107	1.00–1.15	0.30–0.50†	0.025	0.025	0.20–0.35	.....	1.35–1.65	.....
A 6120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.70–0.90	0.10 min.V
A 6145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15 min.V
SAE 6150	0.48–0.55	0.65–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.15 min.V
E 6151	0.47–0.53	0.70–0.90	0.025	0.025	0.20–0.35	.....	0.80–1.10	0.15 min.V
A 6152	0.48–0.55	0.70–0.90	0.040	0.040	0.20–0.35	.....	0.80–1.10	0.10 min.V
A 9255	0.50–0.60	0.70–0.90	0.040	0.040	1.80–2.20	.....	.....	.....
A 9260	0.55–0.65	0.70–0.90	0.040	0.040	1.80–2.20	.....	.....	.....

*Lowest standard maximum phosphorus or sulphur content for acid openhearth or acid electric furnace alloy steel is 0.05% each; silicon is 0.15% min.

†These steels may be specified to either 0.30 to 0.45% or 0.35 to 0.50% manganese, but it is recommended that the full range be allowed wherever possible.

NOTE (a)—Sulphur range: 0.035 to 0.050%.

CODE: A is basic openhearth alloy steel.
B is acid bessemer carbon steel.
C is basic openhearth carbon steel.
D is acid openhearth carbon steel.
E is electric furnace steel.
NE is National Emergency standard steel; designation promulgated by the Office of Production Management.
Q is forging quality, or special requirement quality.
R is re-rolling quality billets.

Basic Openhearth and Acid Bessemer Carbon Steels

Code	Semi-finish	Bars	Wire Rods	C	Mn	P Max.	S Max.
C 1005	—	—	√	0.06 max.	0.35 max.	0.04	0.05
C 1006	Q, R	√	√	0.08 max.	0.25–0.40	0.04	0.05
C 1008	Q, R	√	√	0.10 max.	0.30–0.50	0.04	0.05
CB 1008	—	√	√	0.10 max.	.....	.....	.....
C 1010	Q, R	√	√	0.08–0.13	0.30–0.50	0.04	0.05
C 1012	Q	√	√	0.10–0.15	0.30–0.50	0.04	0.05
CB 1012	—	√	—	0.15 max.	.....	.....	.....
C 1013	—	—	√	0.11–0.16	0.60–0.90	0.04	0.05
C 1014	Q	√	√	0.13–0.18	0.40–0.60	0.04	0.05
C 1015	Q, R	√	√	0.13–0.18	0.30–0.50	0.04	0.05
C 1016	Q	√	√	0.13–0.18	0.60–0.90	0.04	0.05
CB 1017	—	√	—	0.10–0.25	.....	.....	.....
C 1017	Q	√	√	0.15–0.20	0.40–0.60	0.04	0.05
C 1018	Q	√	√	0.15–0.20	0.60–0.90	0.04	0.05
C 1019	Q	√	√	0.15–0.20	0.70–1.00	0.04	0.05
C 1020	Q, R	√	√	0.18–0.23	0.30–0.50	0.04	0.05
C 1021	Q	√	√	0.18–0.23	0.40–0.60	0.04	0.05
C 1022	Q	√	√	0.18–0.23	0.70–1.00	0.04	0.05
C 1023	Q	√	√	0.20–0.25	0.30–0.50	0.04	0.05
C 1024	—	√	—	0.20–0.26	1.35–1.65	0.04	0.05
C 1025	Q, R	√	√	0.22–0.28	0.30–0.50	0.04	0.05
C 1026	Q	√	√	0.22–0.28	0.40–0.60	0.04	0.05
C 1027	—	√	√	0.24–0.30	0.40–0.60	0.04	0.05
C 1029	Q	√	√	0.25–0.31	0.60–0.90	0.04	0.05
C 1030	Q	√	√	0.28–0.34	0.60–0.90	0.04	0.05
CB 1032	R	√	—	0.25–0.40	.....	.....	.....
C 1033	Q	√	—	0.30–0.36	0.60–0.90	0.04	0.05
C 1034	—	—	√	0.32–0.38	0.50–0.70	0.04	0.05
C 1035	Q	√	—	0.32–0.38	0.60–0.90	0.04	0.05
C 1036	—	√	—	0.32–0.39	1.20–1.50	0.04	0.05
C 1038	Q	—	√	0.35–0.42	0.60–0.90	0.04	0.05
C 1040	Q	√	√	0.37–0.44	0.60–0.90	0.04	0.05
C 1041	—	—	√	0.36–0.44	1.35–1.65	0.04	0.05
C 1042	Q	√	—	0.40–0.47	0.60–0.90	0.04	0.05
C 1043	Q	√	—	0.40–0.47	0.70–1.00	0.04	0.05
C 1044	—	—	√	0.43–0.50	0.50–0.70	0.04	0.05
C 1045	Q	√	—	0.43–0.50	0.60–0.90	0.04	0.05
C 1050	Q	√	—	0.48–0.55	0.60–0.90	0.04	0.05
C 1051	—	—	√	0.45–0.56	0.85–1.15	0.04	0.05
C 1052	—	√	—	0.47–0.55	1.20–1.50	0.04	0.05
C 1054	—	—	√	0.50–0.60	0.50–0.70	0.04	0.05
C 1055	Q	√	—	0.50–0.60	0.60–0.90	0.04	0.05
C 1057	—	—	√	0.50–0.61	0.85–1.15	0.04	0.05
C 1059	—	—	√	0.55–0.65	0.50–0.70	0.04	0.05
C 1060	—	√	√	0.55–0.65	0.60–0.90	0.04	0.05
C 1061	—	√	—	0.54–0.65	0.75–1.05	0.04	0.05
C 1062	—	—	√	0.54–0.65	0.85–1.15	0.04	0.05
C 1064	—	√	√	0.60–0.70	0.50–0.70	0.04	0.05
C 1066	—	√	√	0.60–0.71	0.80–1.10	0.04	0.05
C 1068	—	√	—	0.65–0.75	0.50 max.	0.04	0.05
C 1069	—	—	√	0.65–0.75	0.50–0.70	0.04	0.05
C 1070	—	√	—	0.65–0.75	0.70–1.00	0.04	0.05
C 1074	—	√	√	0.70–0.80	0.50–0.70	0.04	0.05
C 1075	—	—	√	0.70–0.80	0.60–0.80	0.04	0.05
C 1078	—	√	√	0.72–0.85	0.30–0.50	0.04	0.05
C 1080	—	√	—	0.75–0.88	0.60–0.90	0.04	0.05
C 1085	Q	√	—	0.80–0.93	0.070–1.00	0.04	0.05
C 1086	—	√	√	0.82–0.95	0.30–0.50	0.04	0.05
C 1095	—	√	√	0.90–1.05	0.30–0.50	0.04	0.05
B 1006	—	—	√	0.08 max.	0.45 max.	0.11	0.06
B 1008	R	√	—	0.10 max.	0.30–0.50	0.11	0.06
B 1011	—	√	√	0.13 max.	0.50–0.70	0.11	0.06

Note 1: When silicon is specified in standard basic openhearth steels, silicon may be ordered only as 0.10 per cent maximum; 0.10 to 0.20 per cent; or 0.15 to 0.30 per cent. In the case of many grades of basic openhearth steel, special practice is necessary in order to comply with a specification including silicon.

Note 2: Acid bessemer steel is not furnished with specified silicon content.

Sulphurized or Phosphorized Carbon Steels

Code	Semi-finish	Bars	Rods	C	Mn	P (b)	S (b)
B 1106	—	—	√	0.09 max.	0.50 max.	0.11 max.	0.04–0.09
C 1108	—	—	√	0.08–0.13	0.50–0.70	0.045 max.	0.07–0.12
C 1109	Q	√	√	0.08–0.13	0.60–0.90	0.045 max.	0.08–0.13
B 1110	—	√	√	0.13 max.	0.60 max.	0.11 max.	0.045–0.075
C 1110	—	√	√	0.08–0.13	0.60–0.90	0.045 max.	0.10–0.15
B 1111	—	√	√	0.08–0.13	0.60–0.90	0.09–0.13	0.10–0.15
C 1111	—	—	√	0.08–0.13	0.60–0.90	0.045 max.	0.16–0.23
B 1112	—	√	√	0.08–0.13	0.60–0.90	0.09–0.13	0.16–0.23
C 1112	—	√	—	0.10–0.16	1.00–1.30	0.045 max.	0.08–0.13
B 1113	—	√	√	0.08–0.13	0.60–0.90	0.09–0.13	0.24–0.33
C 1113	Q	√	—	0.10–0.16	1.00–1.30	0.045 max.	0.24–0.33
C 1115	Q	√	√	0.13–0.18	0.70–1.00	0.045 max.	0.10–0.15
C 1116	Q	√	√	0.14–0.20	1.10–1.40	0.045 max.	0.16–0.23
C 1117	—	√	√	0.14–0.20	1.00–1.30	0.045 max.	0.08–0.13
C 1118	Q	√	√	0.14–0.20	1.30–1.60	0.045 max.	0.08–0.13
C 1119	—	√	√	0.14–0.20	1.35–1.65	0.045 max.	0.16–0.23
C 1120	Q, R	√	√	0.18–0.23	0.60–0.90	0.045 max.	0.08–0.13
C 1121	Q	√	√	0.18–0.23	0.70–1.00	0.045 max.	0.08–0.13
C 1122	Q	√	√	0.17–0.23	1.35–1.65	0.045 max.	0.08–0.13
C 1132	Q	√	√	0.27–0.34	1.35–1.65	0.045 max.	0.08–0.13
C 1137	Q	√	√	0.32–0.39	1.35–1.65	0.045 max.	0.08–0.13
C 1140‡	Q	√	—	0.37–0.44	0.60–0.90	0.045 max.	0.04–0.07
C 1141	—	√	—	0.37–0.45	1.35–1.65	0.045 max.	0.08–0.13
C 1144	—	√	—	0.40–0.48	1.35–1.65	0.045 max.	0.24–0.33
C 1145‡	Q	√	—	0.42–0.49	0.70–1.00	0.045 max.	0.04–0.07
C 1205	Q	—	√	0.08 max.	0.25–0.40	0.04–0.07	0.05 max.
C 1206	R	—	√	0.08 max.	0.25–0.40	0.06–0.10	0.05 max.
C 1209	R	—	√	0.08–0.13	0.30–0.50	0.04–0.07	0.05 max.
C 1210	Q	—	√	0.08–0.13	0.30–0.50	0.06–0.10	0.05 max.
C 1211	—	—	√	0.08–0.13	0.60–0.90	0.09–0.13	0.10–0.15
C 1217	—	√	—	0.14–0.19	0.70–1.00	0.09–0.13	0.20–0.29

(b)—Sulphurized (and phosphorized) steel is not subject to check analysis for sulphur (or phosphorus).

Notes: Acid bessemer steels (B series) are not furnished with specified silicon content.

‡Standard steels C 1140 and C 1145 may be ordered with silicon content either as 0.10% max., 0.10 to 0.20%, or 0.15 to 0.30%.

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ON THE MARCH to aid users of alloys...

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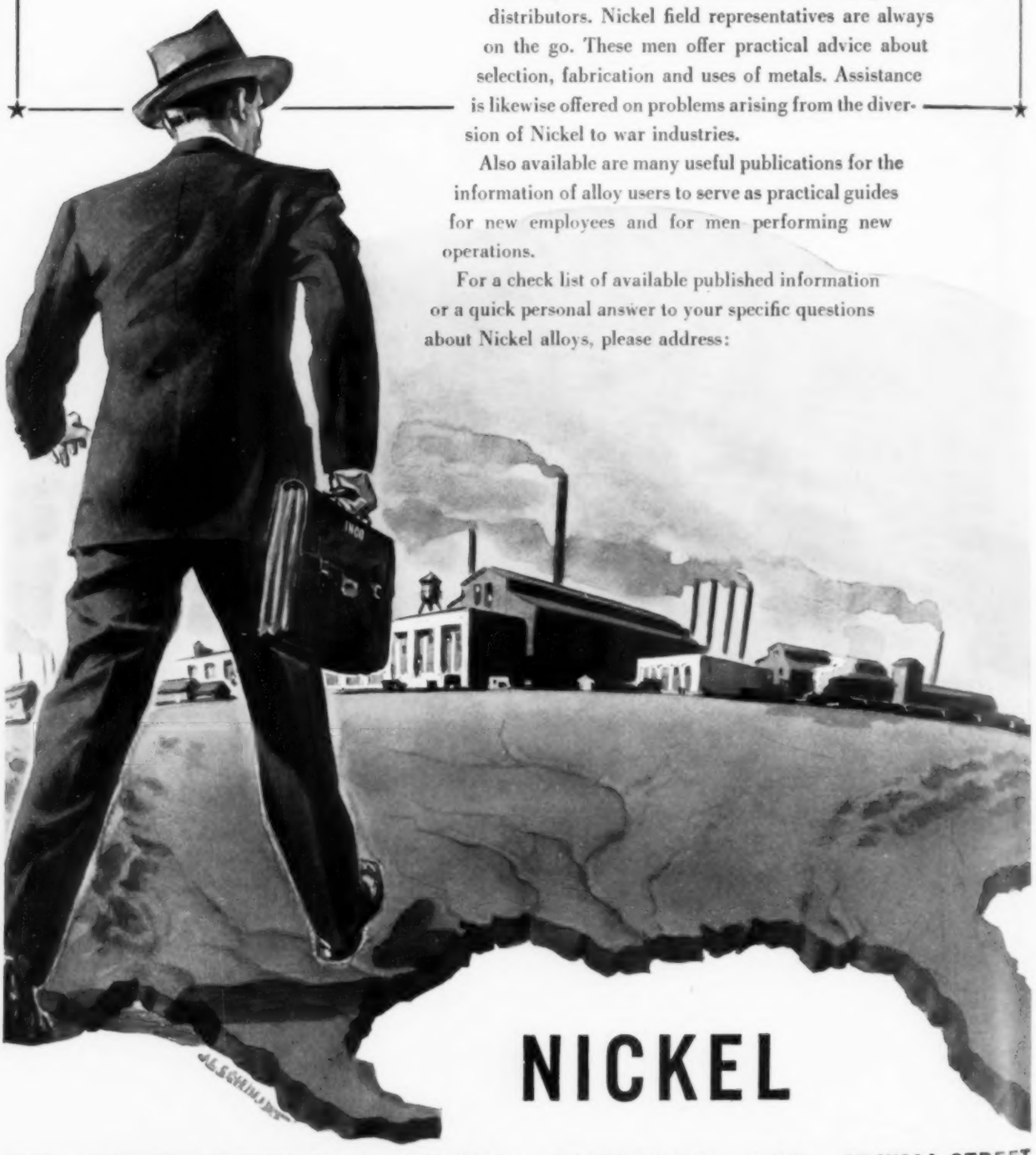


NICKEL

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

Table III — Physical Properties of Carburized Steels

Steel	Direct Quenched				Reheated and Quenched				
	Core Properties			Carburized Izod	Quenching Temperature	Core Properties			Carburized Izod
	Strength	Yield	Izod			Strength	Yield	Izod	
A 2320	150,000	122,000	45	8	1475	135,000	110,000	45	5
A 2512	175,000	148,000	45	10	1475	172,000	140,000	53	8
A 3120	135,000	105,000	32	4	1500	130,000	97,500	40	4
A 3315	208,000	165,000	45	12	1475	210,000	170,000	42	10
A 4022	130,000	95,000	45	2	1525	115,000	90,000	45	3
A 4120	137,000	105,000	35	5	1575	120,000	102,000	40	3
A 4320	180,000	160,000	40	5	1500	185,000	160,000	55	7
A 4620	130,000	100,000	45	4	1500	120,000	95,000	48	4
A 4820	182,000	150,000	42	8	1450	167,000	137,000	57	6
A 5120	128,000	104,000	33	6	1525	119,000	97,000	39	3
A 6120	130,000	110,000	55	4	1500	120,000	86,000	23	2

Some of the currently used standard grades are used in the normalized or normalized and tempered condition with tensile strength values of 65,000 to 105,000 psi.

The most commonly used standard steels in this class and possible alternates therefor are:

Table IV — Semi-Thorough Hardening Steels

Standard Series Designation	Alternate Steels		
	C-Mo	Mn-Mo	Ni-Cr-Mo
A 1330	A 4037	NE 8233	....
A 2330	A 4037	NE 8233	NE 8630
A 3130	A 4037	NE 8233	NE 8630
A 4130	A 4037	NE 8233	NE 8630
A 5130	A 4037	NE 8233	....
SAE 6130	A 4037	NE 8233	NE 8630

[Results of standard end-quench hardenability tests for each of the standard steels in Table IV are shown in the diagrams accompanying this article. The diagrams are reproduced from the American Iron & Steel Institute's pamphlet, and each gives hardenability curves for steels closely approximating the composition of the alternates.]

Because an excessive amount of time would have been consumed in making standard physical property tests of all the alternate compositions set forth, the committee was of the opinion that for general applications a comparison of standard end-quench hardenability data would suffice as a useful guide to their application.

All available end-quench hardenability data were accumulated from members of the committee and comparisons were made. Where no data were available several manufacturers generously produced a sufficient number of experimental heats to complete the program. The accumulated data were compared in detail to determine how the characteristics of the alternates would compare with the characteristics of well-known steels.

In addition to armament purposes the principal uses of the 0.30% carbon grades are:

1300 Series for automotive axle shafts and shackle bolts.

2300 Series for aircraft bolts, die-lock chain and gun and tank parts.

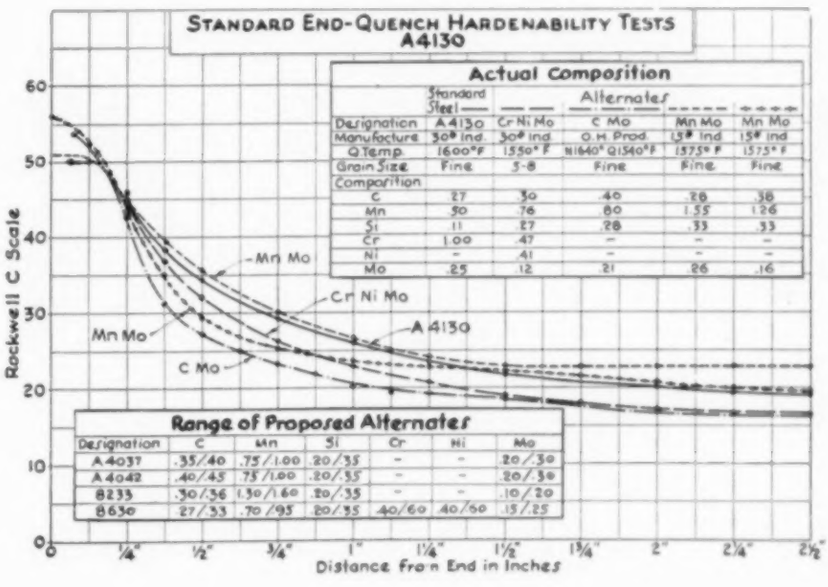
4100 Series for aircraft sheets, tubing and bars for welding and heat treatment, or both; for bolts and scarifier teeth.

5100 Series for automotive side gears.

6100 Series for aircraft propeller blades.

Thorough-Hardening Grades

The thorough-hardening alloy steels most commonly used may be divided into five distinct classes as follows:


STANDARD END-QUENCH HARDENABILITY TESTS
A4130
Actual Composition
Standard Steel
Alternates
Designation A4130 Cr Ni Mo C Mo Mn Mo Mn Mo
Manufacture 30# Ind. 30# Ind. O.H. Prod. 13# Ind 15# Ind
Q.Temp. 1600°F 1550°F N1640° Q1540°F 1575°F 1575°F
Grain Size Fine 5-8 Fine Fine Fine
Composition
C .27 .30 .40 .28 .38
Mn .50 .76 .80 1.55 1.26
Si .11 .27 .28 .33 .33
Cr 1.00 .47 - - -
Ni - .41 - - -
Mo .25 .12 .21 .26 .16
Mn Mo
Cr Ni Mo
A 4130
Mn Mo
C Mo
Rockwell C Scale
Range of Proposed Alternates
Designation C Mn Si Cr Ni Mo
A 4037 .35/.40 .75/1.00 .20/.35 - - .20/.30
A 4042 .40/.45 .75/1.00 .20/.35 - - .20/.30
8233 .30/.36 1.30/1.60 .20/.35 - - .10/.20
8630 .27/.33 .70/.95 .20/.35 .40/.60 .40/.60 .15/.25
Distance from End in Inches

1. Those used in the full-hardened state, tempered to about 400° F. with resultant Brinell hardness of 550 to 600, with tensile strengths of about 275,000 to 300,000 psi.

2. Those treated to Brinell 350 to 450 with tensile strengths of about 175,000 to 225,000 psi.

3. Those treated to Brinell 260 to 350 with tensile strengths of about 125,000 to 170,000 psi.

4. A specialty class of alloy steels containing approximately 0.60% carbon, used for a variety of purposes such as piston rods, rams, sow blocks, trimmer dies, shear blades, and hot-work dies. The steels of this group which are most commonly used are chromium-nickel steels, chromium-nickel-molybdenum-copper steels and chromium-nickel-molybdenum-vanadium steels. It will be most difficult to duplicate the properties of such steels with other chemistry combinations without considerable experimental work, except in the cases where some experience has been gained, as for example, manganese-molybdenum steels for shear blades. Wherever the hardenability characteristics compare favorably, these alternate steels have possibilities for satisfactory use.

5. The high carbon alloy types such as the 52000 series bearing steels which have unusually high resistance to wear. Such steels are used at the maximum hardness obtainable for the section involved.

A list of the most commonly used standard thorough-hardening steels and possible alternates therefor is shown in Table V.

[Hardening characteristics of representative standard steels — 2340, 3140, 3240, 4140, 5140 and 6140 as well as the alternate steels 4050 and 4065 — as measured by hardness traverses, edge to center, of oil or water quenched bars, 1 to 5 in. diameter, were presented in a data sheet in METAL PROGRESS, October 1941 Reference Issue, page 522. Similar curves for the other alternate steels in the NE 8000 series will be presented as soon as they are available.]

In addition to armament purposes the principal uses of the thorough-hardening grades are as follows:

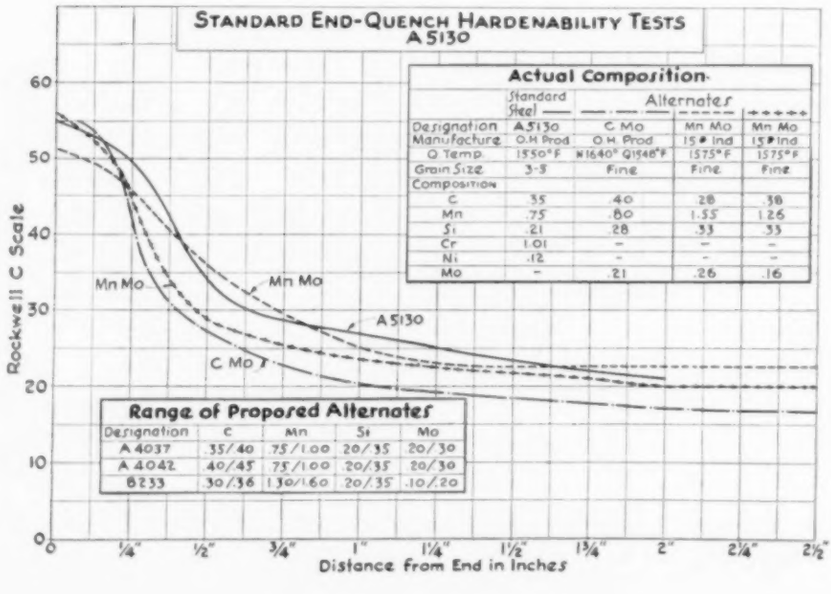
1300 Series for automotive transmission gears, spline shafts, knuckles, arms and shackle bolts.

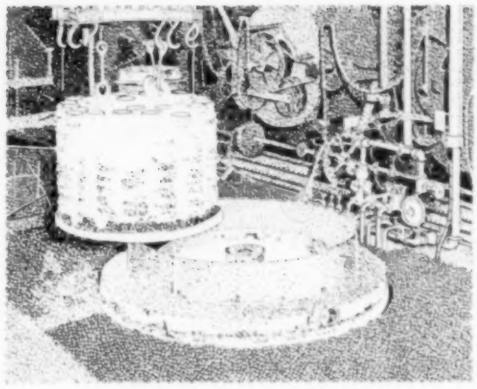
2300 Series for aircraft engine parts such as connecting rods, connecting rod bolts, crankcase bolts, studs, keys, propeller shafts, generator shafts, pump shafts, rocker arms and gears. They are also used in the machine tool industry for gears, collets, cams, shafting, feed fingers, tool holders, and for pneumatic tool barrels and pistons. In the textile and printing industries steels of this series are used for rollers, and for rotors and shafts in prime movers. In oil refinery equipment for low temperature pressure vessels, for pipe valves and fittings, and in marine engines for camshafts and propeller shafts. They also find use in eye bars, booms, tie plates and trusses in constructional work and

Table V — Thorough-Hardening Steels

STANDARD SERIES DESIGNATION	ALTERNATE STEELS		
	C-Mo	MN-MO	NI-CR-MO
A 1340	A 4047	NE 8245	....
A 2335	A 4063	NE 8339	NE 8739
A 2340	A 4068	NE 8442	NE 8744
A 2345	A 4068	NE 8447	NE 8749
WD 2350	A 4068	NE 8547	NE 8949
A 3045	A 4068	NE 8442	NE 8744
A 3135	A 4063	NE 8339	NE 8739
A 3140	A 4068	NE 8442	NE 8744
A 3141	A 4068	NE 8447	NE 8749
A 3145	A 4068	NE 8447	NE 8749
A 3150	A 4068	NE 8547	NE 8949
A 3240	A 4068	NE 8442	NE 8744
WD 3250	A 4068	NE 8547	NE 8949
A 4137	A 4063	NE 8339	NE 8739
A 4142	A 4063	NE 8442	NE 8744
A 4145	A 4068	NE 8447	NE 8749
A 4150	A 4068★	NE 8547	NE 8949
A 4340	A 4068★	NE 8547	NE 8949
A 4640	A 4063	NE 8339	NE 8739
A 4645	A 4068	NE 8447	NE 8744
4650	A 4068	NE 8547	NE 8949
A 5045	A 4063	NE 8339	....
A 5140	A 4063	NE 8339	....
A 5145	A 4068	NE 8442	....
A 5150	A 4068	NE 8447	....
WD 6140	A 4063	NE 8339	NE 8739
A 6145	A 4068	NE 8442	NE 8744
A 6150	A 4068	NE 8447	NE 8749
A 9260	A 4068★★	....	....

★Recommended especially for small tools.
★★Recommended if silicon becomes critical.





for ...draulic valves.
...0 *Series* for automo... steering arms, steer... knuckle supports and ...nsmission gears.
3100 Series for aircraft engine parts such as bolts, nuts, studs, connecting rods and crankshafts. In the automotive industry they are used for steering arms and knuckles, knuckle pins, crankshafts; differential drive pinions, pinion shafts and ring and side gears; propeller shafts, rear axles, transmission gears and transmission spline shafts. They are used also for cantilever pins in bridges and winch shafts; for die blocks, die casting dies. In the machine tool industry they are used for shafting, precision lead screws and spindles; in marine engines for crankshafts and engine bolts; in the oil industry for bolts, couplings, side bars in draw works chains, draw works shafting, drill collars, jars, kelly bars, reamer bodies, rotary table shafts, slush pump rods and tool joints.

3300 Series for heavy duty shafting, tank transmission gears and gun bolts.

4000 Series for automotive bolts, pinion shafts, front and rear axles, leaf and coil springs, sway bars, cylinder head studs and steering arms and knuckles. They are used for such hand tools as chisels, hammers, and screw drivers and for chain pins, pneumatic tool bits, scraper blades and draw works chain pins.

4100 Series for aircraft engine parts such as propeller blades, bolts, nuts, studs, connecting rods, crankshafts, cylinder liners, and aircraft structural shapes and tubing. In the automotive industry for steering arms and knuckles, connecting rods, crankshafts, transmission spline shafts, rear axles and trailer axles. They are also used for structural eye bars, cantilever and chain pins, sprockets, and winch shafts. In hydraulic machinery for impellers, rams and shafts and in machine tools for precision lead screws, spindles and tool holders; in marine engines for crankshafts and engine bolts; for connecting rods, shafts and spindles in mill equipment. In the oil industry these steels are used for bolts, couplings, draw works side bars and shafting, drill collars, jars, kelly bars, reamer bodies, pony rods, pull rods, rotary table shafting, slush pump rods and tool joints.

4300 Series for aircraft engine parts such as crankshafts, propeller shafts and connecting rods and for automotive crankshafts and rear axles; also for blanking, cold heading, and die casting dies, crank and propeller shafts, dredge bucket teeth, and high temperature bolts for oil refineries.

4600 Series for forgings for aircraft engines, tractor gears, automotive transmission gears, splines, and small hand tools.

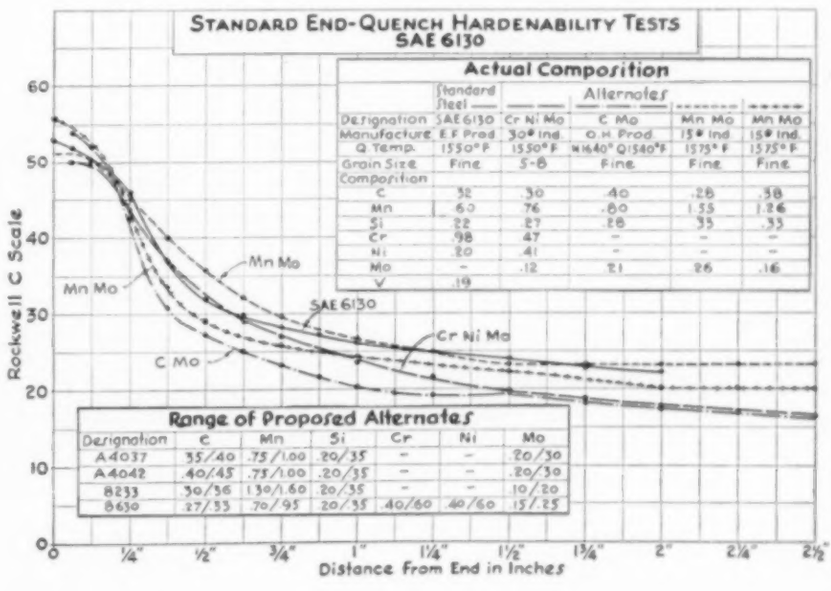
5000 Series for clutch shafts and transmission main shafts.

5100 Series for automotive leaf and coil springs, steering worms, transmission gears and transmission spline shafts. They are also used for digger bucket teeth, scarifier teeth, machine tool gears, crusher jaws and hand hammers.

52000 Series — The principal use of this steel is for anti-friction (ball and roller) bearings.

6100 Series for aircraft engine parts such as propeller hubs and blades, coil springs, piston pins, knuckle pins, connecting rods and crankshafts. They are used in the automotive industry for differential pinion and side gears and leaf and coil springs. Hand chisels, hammers, pliers, screw drivers and wrenches are made from this series as well as marine engine crankshafts, mill shafting, well driller screens, small crankshafts for pneumatic machines, pneumatic bits, valves and valve seats. Other general uses are for locomotive springs, oil refinery equipment such as bolts for high temperature service, pistons and plungers and parts for pressure vessels; also for valve springs, scarifier teeth, winch shafts, hot-work die blocks, hydraulic pistons and shafts; in the machine tool industry for gears, chuck jaws, precision lead screws, spindles and tool holders.

9200 Series for automotive, tractor and railroad leaf and coil springs. They are also used for tools such as malls, sledges, chipping chisels, cutter wheels and coal mine cutters.


STANDARD END-QUENCH HARDENABILITY TESTS
SAE 6130
Actual Composition
Standard Steel
Alternates
Designation SAE 6130 Cr Ni Mo C Mo Mn Mo Mn Mo
Manufacture E F Prod 30# Ind O H Prod 15# Ind 15# Ind
Q Temp 1550°F 1550°F N1640° Q1540°F 1575°F 1575°F
Grain Size Fine 5-8 Fine Fine Fine
Composition
C .32 .30 .40 .28 .38
Mn .60 .76 .60 1.55 1.26
Si .22 .27 .28 .35 .35
Cr .98 .47 - - -
Ni .20 .41 - - -
Mo - .12 .21 .26 .16
V .19
Range of Proposed Alternates
Designation C Mn Si Cr Ni Mo
A4037 .35/.40 .75/1.00 .20/.35 - - .20/.30
A4042 .40/.45 .75/1.00 .20/.35 - - .20/.30
8233 .30/.36 1.30/1.60 .20/.35 - - .10/.20
8630 .27/.33 .70/.95 .20/.35 .40/.60 .40/.60 .15/.25
Rockwell C Scale
Distance From End in Inches
Mn Mo
Mn Mo
SAE 6130
Cr Ni Mo
C Mo

War Products Consultation

Pickling of 3.5% Nickel Steel and 1.3% Chromium Steel

The Problem

Encountered by a Shop
Newly Contracting for the Navy

WE HAVE a problem of removing the scale from steel rods and forgings fairly high in alloy for Navy parts, especially steels 2330 and 52100, hot rolled and annealed. There are a number of these parts which have caused considerable difficulty in the cleaning house. If any ASMembers have successfully licked this problem, we would like to learn of the acidities, temperatures, and acids used.

Suggested Solutions for Chromium Steel

By a Ball Bearing Manufacturer: No serious problem on 52100 wire or forgings when using 4% H_2SO_4 at 140° F. "We also use 'Hibitrite' as an inhibitor in this solution. It usually takes about 60 to 90 min. to pickle a 1000-lb. basket of forgings satisfactorily for machining. Wire pickles in a considerably shorter period of time, as we put it through a scale breaker prior to pickling. If the forgings lend themselves to blasting, then a 'rotoblast' or 'tumblast' using fairly coarse grit is quite satisfactory."

By a Roller Bearing Manufacturer: "If at all possible, the scale should be broken, previously, by dipping in saturated salt solution. Tumbling tubs are definitely better than still solutions. We would suggest the use of 'Shell' acid if it is available, using about 10 to 12% acid at a temperature of 145 to 155° F. for the bath. The iron content should be under 5%."

Another Ball Bearing Manufacturer regularly etches 52100 steel to reveal surface defects, a much more severe process than ordinary pickling or sandblasting. "Our standard practice is to immerse the bars in hot acid solution containing 50% muriatic acid and about a tablespoonful of 'rodine' (product of the American Chemical Paint Co., Ambler, Pa.). This prevents excessive pitting. Work that is slightly scaled requires 10 min.; badly scaled steel might require 40 min. The operator must watch the metal carefully to be sure it is not etched too deeply or pitted. Steel mills prefer a 25% H_2SO_4 solution for this etching operation. A few use 10% H_2SO_4, 38% HCl, and the balance water. Both of these mixtures act more slowly and are easier to control. After etching, most mills dip in water and then in a lime solution to prevent rusting. Parts in contact must be moved, else scaled areas will remain."

Suggested Solutions for Nickel Steel

By an Alloy Steel Manufacturer: No serious problem on rods, bars or forgings. "Where heavy scale is encountered such as on material furnace cooled from the mill, a 3½% (by volume) H_2SO_4 bath at 175° F. is used; the time depends on the grade and amount of scale. Bars off the finishing mills with light scale are given a faster pickle in approximately 5% H_2SO_4 at 175° F. Heat treated bars are currently pickled in a 6 to 8% H_2SO_4 bath at 160 to 180° F. When scale is thick and resistant to pickling there is danger of over-pickling the bar ends, so it is better to use a weaker solution and a longer time. Forgings to be subsequently machined do not present as difficult a problem as do bars on which tolerances and final finish must be considered."

By a Gear Maker: Normalized forgings with rather heavy scale are pickled in 12% H_2SO_4 by volume at 160° F. Time: 30 min. to 1 hr. with agitation is sufficient. Acid as purchased is 68° Bé, and 1000 gal. of solution is made up, to which 0.3% by weight of E. F. Houghton's inhibitor known as "acitrol" is added.

By a Manufacturer of Cold Drawn Bars: "It is not difficult to pickle 2330 in the hot rolled condition in a straight H_2SO_4 bath, approximately 8% by weight acid, at 180° F. However, annealing to soften is quite a long operation, and the annealing scale on top of the hot rolled scale does present considerable difficulty which

can be eliminated by protecting the material during annealing or by various mechanical aids to remove the scale.

"1. Protection during annealing: *(a)* Pickle the hot rolled steel, then anneal in 'Charmo Gas' protective atmosphere. *(b)* Cover the steel with roll-scale and heat under hoods similar to those used in sheet annealing; this results in a scale that is easily removed.

"2. Mechanical methods: *(a)* On coil stock we pass the rods through a set of staggered rolls; this mechanically knocks off most of the scale, and the rest is comparatively easily pickled. *(b)* The descaling blowpipe put out by The Linde Air Products Co. has possibilities. *(c)* Pass the material through shot blasters; although slow, this does a good job on bad scale.

"The ideal condition would be to pickle the hot rolled bar and anneal under protected atmosphere."

Critique by F. L. LaQue

Development and Research Division
International Nickel Co.

THE MOST important observation is that pickling of nickel steels apparently has not been recognized as a serious problem. I have learned from the Electro Metallurgical Co. that this is true also of the low chromium steels. At any rate, we have had no occasion to direct special attention to the pickling of nickel steels in our research laboratory, and it has not received much attention in the technical literature. The usual procedures for the pickling of carbon steel have been adequate.

C. H. McCollam and D. L. Warrick in *Transactions* of the A.S.M., 1936, page 133, found that the electrolytic potential between bare steel and scale, which was a controlling factor in pickle *pitting*, was determined largely by the temperature at which the scale formed; the dividing line for unfavorable potentials tended to coincide with the transformation temperature.

In the many cases where the temperature of scaling cannot be limited to suit subsequent pickling, the problem may be ameliorated by removing as much scale as possible by mechanical means prior to pickling, and by using one of the common inhibitors in the pickle bath. The bath itself could be about 8 to 10% by weight H_2SO_4 operated at about 150° F. and agitated. (Imhoff has suggested that it be kept under 140° F.) If practical, the pickle should be a fresh one. For forgings, an acid concentration of 8 to 15% and temperature of about 150° F. have been recommended. Interruption of the pickling operation so as to permit intermediate mechanical removal of loosened scale is often helpful.

There have been occasional suggestions as to the desirability of including HCl in pickles for alloy steels. We know that a 10 to 15% by weight solution of HCl at about 140° F. is effective, especially when loosened scale is brushed off. As an alternate, a small percentage, say 2%, might be added to the sulphuric acid pickle mentioned previously.

Increasing Production by Elimination of Unnecessary Alloys

By D. K. Crampton
Director of Research
Chase Brass & Copper Co.
Waterbury, Conn.

THE GENERAL ADVANTAGES of a simplification plan for any product are perhaps now so well recognized as to need no further discussion here. [This verbatim transcript of remarks made before the National Defense Meeting on conservation of copper and its alloys at the ASM Annual Convention in Philadelphia, is still very much to the point.] The specific advantages resulting from a reduction of the number of alloys actively made in a given mill may not be so obvious. However they are very important and will be discussed briefly. While particular reference will be made to the situation existing in mills producing wrought copper alloys, it is probable that the same general situation holds with respect to other metals.

Prior to the present emergency, the copper and brass producers listed an extremely large number of alloys. Many of these were in reality but slight modifications of certain general types, but made at one time or another. The lists of mixtures number in the hundreds. This situation resulted partly from the insistence of various consumers and specification-making bodies, and partly through zealous but not always farsighted promotional work by the producers themselves.

It is noted that there have been as many as ten different variations of nominally "lead-free high brass" in sheet and strip form, whereas all real needs as indicated by properties of the materials or normal use could be met by not more than three. At one time it was noted that seven distinct variations of "naval brass" were being produced, whereas every known application of such material could be adequately served by two or possibly three modifications.

In times of normal business, there might be sufficient justification for such a situation. While producers would realize that the many alloys and variations make for increase of production cost and decrease of production rate, the desire to satisfy both real and fancied needs is defensible. During the present emergency, however, such considerations are certainly of very minor importance and emphasis should be placed on the greatest possible production of the least number of alloys to adequately serve essential purposes.

Since the start of the emergency, Chase Brass & Copper Co. has on two occasions, with the cooperation of consumers, markedly reduced the number of active mixtures so that the list has now been reduced to 45 alloys. It is possible that some further reduction might be made, but this would be slight compared to that already effected. It is known that other producers have taken similar steps and the benefits are now probably spread over the industry as a whole.

The advantages of such a simplification program are felt both in the casting shop and in the mill.

In the casting shop time is lost in shifting from one alloy to another on a given furnace. Possibly it is not generally realized by customers that induction furnaces are used throughout the industry, in which at all times it is neces-

sary to maintain a considerable amount of molten metal; it is impossible to start these furnaces operating otherwise. While minor changes in alloy may be made in a few instances by correcting for the composition of the molten metal held over from one pouring to the next, any considerable change is impossible without pouring the furnace clean and re-priming with molten metal of the desired new composition, which has to be taken from another furnace already operating on that mixture or else prepared specially in a small auxiliary melter. In any event, the time required to change is considerable and represents a production loss.

A point of even greater importance in this connection is that on a large number of such changes there is contamination of the new alloy from the furnace lining which can only be prevented by one or more wash-out heats, each of which represents a total loss of production and presents a further problem in getting rid of the mongrel alloy thus produced. Sometimes as many as four or five such wash-out heats are necessary to clean the furnace lining effectively so as to prevent subsequent contamination.

A second advantage of long runs on single compositions resides in the improvement in quality of ingots and castings due to the workmen's greater familiarity with fewer alloys. It must be realized that each alloy requires certain special conditions of melting and pouring for optimum quality. Especially with much relatively green labor, the problem of insuring such best conditions is considerable. Lack of attention to detail results in rejection of many heats for poor quality or for improper analysis, either of which means a loss of production.

This program of simplifying the list of current alloys also simplifies the problem of scrap returns from mill operations. Even under the best conditions, the segregation and intelligent use of scrap in the charge room to maintain established composition limits is a major problem, but the more alloys involved and the more which must meet rigid specification limits, the greater the problem becomes. The number of heats of incorrect composition (each representing a total loss of production) is an increasing function of the number of different alloys made at a given time.

Advantages of a simplified list of alloys extend beyond the casting shop. In the mill many factors contribute to an increase of production with decrease of number of active alloys. Consider, for instance, the loss of time in changing over production or annealing equipment from one alloy to another. In many operations (such as extrusion or hot rolling) marked differences in correct temperatures of working, from one alloy to another, necessitate changes in the billet or cake heating furnaces. Also many changes in the production machine set-up and operation incident to a change from one alloy to another are quite time-consuming. All such time used for these changes represents a total loss of production, and in many instances it is quite serious.

The same problem is met in annealing. In present-day practice much more accurate control of annealing is necessary than previously. Likewise there is a considerable use of automatic conveyor furnaces. Such equipment is of course ideal for long runs under constant conditions, but is not too well adapted to frequent change. Where either the temperature or time cycle has to be changed, it is usually necessary for the annealing furnace to run idle long enough for one lot of material to get out before the new lot starts through. Such idle time means a complete loss of production. In addition in the desire of the workmen to reduce this idle period as much as possible, the time allowed is sometimes inadequate to bring the furnace into its new operating conditions, and this results in improper treatment of some material, which in turn results in its rejection. More loss of production!

Some alloys are much more difficult to produce, cause more wear and upkeep on machines and tools, require more operations, or need more supervision than do others. For these reasons the production per man-hour and per machine-hour varies markedly from one alloy to another, and if the more difficult alloys can be eliminated, the effect is a decided increase in production rate.

The points discussed above should merely be considered as illustrative. Many other items might be mentioned in connection with the effect of the number of active alloys on production rate. The importance of the whole program cannot be too greatly emphasized, and the continued and increased cooperation of consumers and specification-making bodies is earnestly sought in making such projects a very real contribution to the national program. For instance, the paper industry has cut the 82 standard grades to 52, the 10,178 stock items to 2,549. Estimated saving will be 175,000 tons of pulp (approximately 12% of 1941 consumption).

A New Alloy for Working at High Temperature

By P. H. Brace
Westinghouse Research Laboratories
East Pittsburgh, Pa.

SEVERAL years ago the search for an alloy that could be used in place of platinum for oxide-coated filaments in vacuum tubes resulted in a nickel-cobalt-titanium-iron alloy that possessed the necessary electrical and thermionic properties and strength when hot. This alloy was named "Konal". The favorable mechanical behavior of Konal at high temperatures in a vacuum soon attracted attention. Tensile tests showed an ultimate strength of 60,000 psi. or somewhat more at 600° C. (1100° F.). This stimulated efforts to find other alloys of the same basic ingredients having equal or better mechanical properties than Konal and, in addition, enough resistance to oxidation and corrosion to make them useful for high-temperature service under industrial conditions.

Some 200 alloys based on nickel, cobalt, titanium, and iron were prepared to study the effects of various auxiliary elements like chromium, aluminum, tungsten, molybdenum, manganese, and silicon. Several interesting alloys came to light and of these, one, designated as "K-42-B", was selected for more detailed study. Its strength at 600° C. was approximately twice that of Konal, and it had high resistance to oxidation at high temperatures as well as satisfactory balance among other properties such as ductility, workability, corrosion resistance and response to heat treatment.

Chemical analysis of a particular specimen, together with the range of the elements in alloys that come under the designation K-42-B are:

Element	Specimen V-175	Range of Composition
Nickel	46.1 %	40 to 50%
Cobalt	24.86%	20 to 30%
Titanium	2.19%	1 to 4 %
Iron	7.02%	5 to 15%
Chromium	18.74%	15 to 30%

There may also be present minor proportions of aluminum, carbon, manganese, and silicon.

Tensile Properties are listed below. Tests were made after a conditioning treatment which consisted of heating for approximately 2 hr. at 950° C. (1742° F.), quenching in water, and temper hardening by reheating to 650° C. (1202° F.) for 72 hr.

Property	At 70° F.	At 600° C. (1110° F.)
Proportional limit	70,000 psi.	57,500 psi.
Yield strength 0.2% plastic deformation	104,000 psi.	86,000 psi.
0.5% plastic deformation	103,500 psi.	85,100 psi.
Tensile strength	164,750 psi.	127,100 psi.
Elastic modulus	29,000,000 psi.	25,000,000 psi.*
Elongation in 2 in.	29.0%	21.5%
Reduction of area	37.0%	21.7%

*Approximate.

These data were obtained on specimens 0.505-in. diameter, during slow tensile tests in which the time to fracture was held closely at 30 min. Autographic stress-strain curves provided data for calculation of the yield.

Creep Tests — This favorable showing is well supported by the outcome of creep tests extending beyond 10,000 hr. at 1000° F. (540° C.) under stresses of 20,000, 40,000, and 50,000 psi. Results of two tests are shown by Fig. 1.

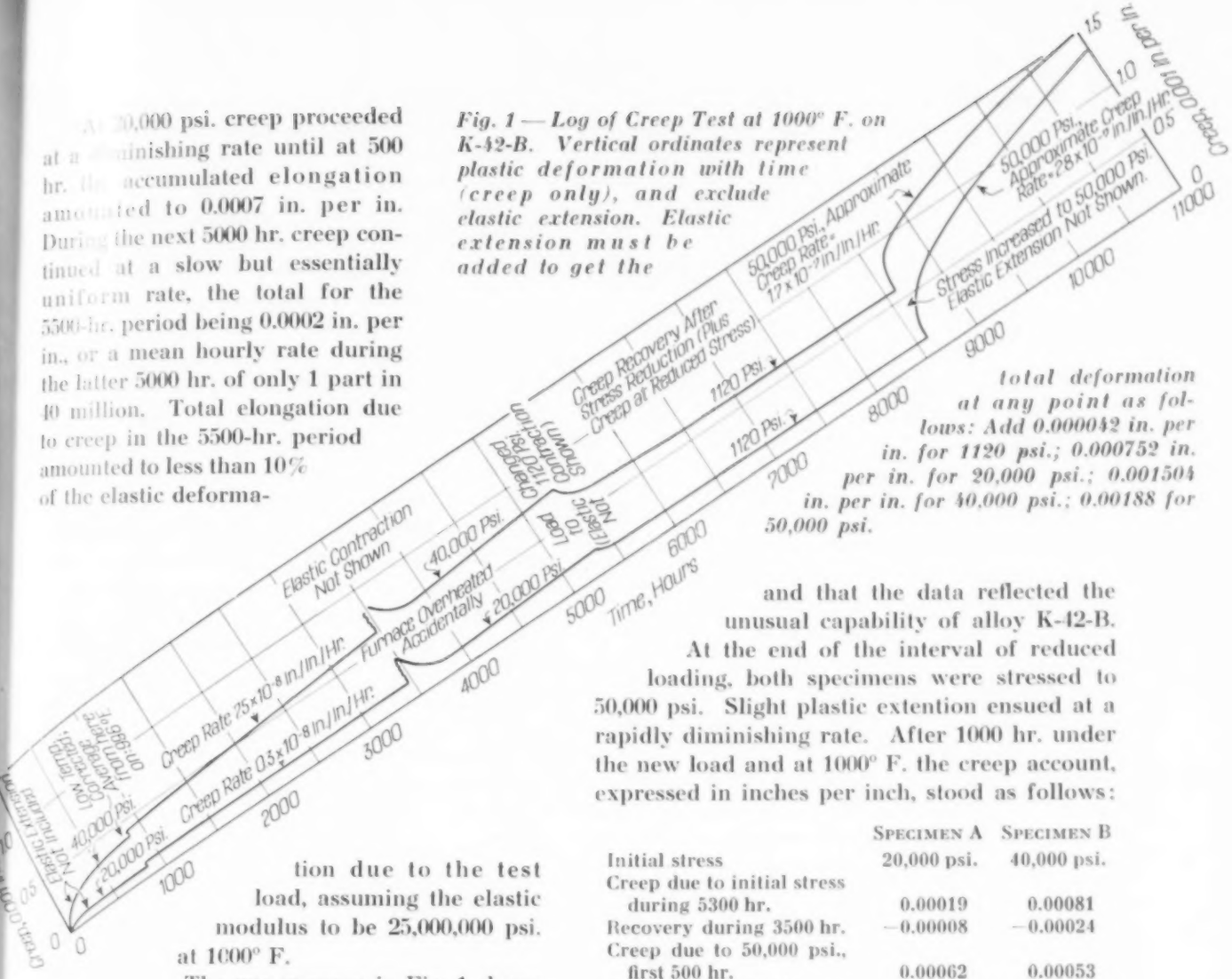

Creep, 0.0001 in per in.
Time, Hours
Elastic Contraction Not Shown
40,000 Psi.
20,000 Psi.
Creep Rate 7.5×10⁻⁸ in./in./Hr.
Creep Rate 0.5×10⁻⁸ in./in./Hr.
Furnace Overheated Accidentally
Load Off
Contraction (Not Shown)
Creep Recovery After Stress Reduction (Plus Creep at Reduced Stress)
1120 Psi.
50,000 Psi., Approximate Creep Rate* 1.7×10⁻⁷ in/in/Hr.
50,000 Psi., Approximate Creep Rate* 2.8×10⁻⁷ in/in/Hr.
Stress Increased to 50,000 Psi. Elastic Extension Not Shown.

Fig. 1 — Log of Creep Test at 1000° F. on K-42-B. Vertical ordinates represent plastic deformation with time (creep only), and exclude elastic extension. Elastic extension must be added to get the total deformation at any point as follows: Add 0.000042 in. per in. for 1120 psi.; 0.000752 in. per in. for 20,000 psi.; 0.001504 in. per in. for 40,000 psi.; 0.00188 for 50,000 psi.

At 20,000 psi. creep proceeded at a diminishing rate until at 500 hr. the accumulated elongation amounted to 0.0007 in. per in. During the next 5000 hr. creep continued at a slow but essentially uniform rate, the total for the 5500-hr. period being 0.0002 in. per in., or a mean hourly rate during the latter 5000 hr. of only 1 part in 40 million. Total elongation due to creep in the 5500-hr. period amounted to less than 10% of the elastic deformation due to the test load, assuming the elastic modulus to be 25,000,000 psi. at 1000° F.

The upper curve in Fig. 1 shows that with stress at 40,000 psi. creep amounted to 0.00031 in. per in. at 500 hr. and had increased to 0.00081 at 5500 hr. The mean hourly rate between 500 and 5000 hr. was thus approximately 1 part in 8 million.

Shortly after the close of the 5500-hr. period the stresses on both specimens were reduced to 1120 psi. As is usual, this caused a slow recovery, proceeding at a diminishing rate for some 300 hr. after the reduction of stress, by which time creep recovery amounted to 0.00005 in. per in. for the specimen previously loaded to 20,000 psi., and 0.00015 in. per in. for the other. Observations were continued for some 3000 hr. under the reduced load but there were no indications of any continuing dimensional change due to constitutional or structural changes. This indicated that the remarkable creep performance was not due to some fortuitous combination of circumstances whereby contraction due to constitutional changes partially counteracted elongation due to creep. The conclusion was that we were observing essentially pure creep and that the data reflected the unusual capability of alloy K-42-B.

At the end of the interval of reduced loading, both specimens were stressed to 50,000 psi. Slight plastic extention ensued at a rapidly diminishing rate. After 1000 hr. under the new load and at 1000° F. the creep account, expressed in inches per inch, stood as follows:

	Specimen A	Specimen B
Initial stress	20,000 psi.	40,000 psi.
Creep due to initial stress during 5300 hr.	0.00019	0.00081
Recovery during 3500 hr.	−0.00008	−0.00024
Creep due to 50,000 psi., first 500 hr.	0.00062	0.00053
Creep due to 50,000 psi. from end of first 500 hr. to 3500 hr.	0.00077	0.00053
Net total for the test:	0.00150	0.00163

Performance of the two specimens in the latter period of testing, when stressed at 50,000 psi., was markedly affected by the previous history. Specimen B, initially loaded at 40,000 psi. showed so much less creep at 50,000 psi. than specimen A (initially loaded at 20,000 psi.) that after 3500 hr. at 50,000 psi. the net totals of creep for the two specimens were not far different. The greater creep in Specimen B due to higher initial stress seemingly had caused significant strain hardening and consequently lower creep rates when the final high stress was applied. This suggests that by means of cold working it may be practicable to improve creep resistance of K-42-B over and above that indicated by the foregoing data.

In any event, hourly creep rates of the order shown (2.8 and 1.7 parts in 10 million for specimens A and B respectively at 1000° F.

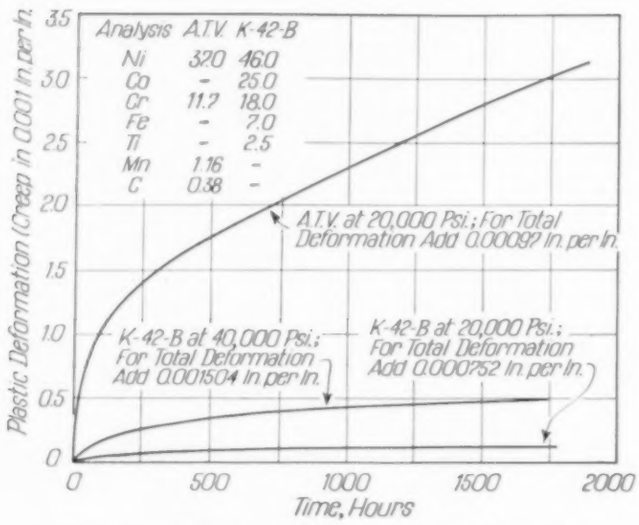


Fig. 2 — Comparative Creep Tests For 1750 Hr. at 1000° F. A.T.V. steel is used for high temperature turbine blades. K-42-B at double the load has many times the creep resistance

and 50,000 psi.) are quite noteworthy. Compare them with the rate of 300 parts per 10 million per hr. for 27 Cr, 22 Ni alloy at 1000° F. and 50,000 psi., the best of the alloys quoted on page 563 of "The Book of Stainless Steels".

Particular attention should be given to a comparison between the elastic deformation which occurred as soon as the specimens were stressed and the total creep which took place during the first 5000 hr. of the test. Even at the high stress of 40,000 psi. the elongation due to creep (0.078%) is scarcely more than half that due to elastic stretch, while at 20,000 psi. the creep effect (0.018%) is almost negligible.

When evaluating a material it is helpful to observe its performance under similar test conditions in comparison with that of other materials intended for the same sort of use. Therefore, comparative creep data at 1000° F. for K-42-B and a high nickel-chromium steel are shown by Fig. 2. The steel has found considerable use at high temperatures in the form of turbine blading, machine parts, and various structural elements, and may be regarded as a commercially accepted high temperature alloy. It will be seen that even at 40,000 psi. K-42-B shows total plastic elongation and creep rates that are negligible in comparison with those of the nickel-chromium steel at the same temperature and half the stress.

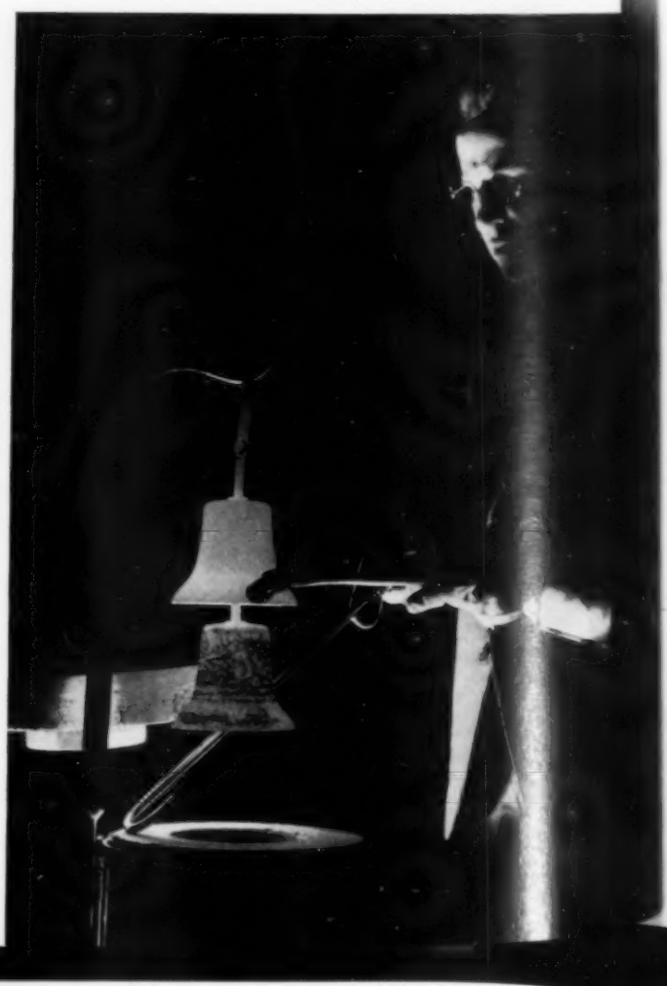
Figure 3 shows that K-42-B retains its strength and elasticity at unusually high temperatures. Two bells, one of K-42-B and the other of steel, were heated in a furnace to a full red heat (1475° F.), withdrawn and immediately struck with a hammer. The K-42-B bell rang with a sustained, clear note, while the steel gave only a dull thud.

Creep data at higher temperatures by Austin and Nickol in *Journal* of the Iron and Steel Institute, 1938-I, are presented in Fig. 4. Here the performance of K-42-B at 800° C. (1472° F.) is compared with that of two alloys in commercial use. These results lead to the conclusion that the relatively good performance of K-42-B extends to temperatures as high as 1000° C. (1800° F.).

Another interesting comparison is shown by Fig. 5. Cantilever specimens of K-42-B and the related alloys Konal and K-52, along with 18-8 stainless steel and 20% chromium-iron alloy, were held at temperatures in the neighborhood of 2350° F. (1250° C.) for 30 hr. The superiority of the new alloys is evidenced by the fact that they are showing no visible sagging. The only forces acting were those due to the weight of the specimens.

Oxidation Resistance — If an alloy having high strength at high temperatures is to be of more than limited interest in the industrial field it must also possess adequate resistance to oxidation, so the table opposite shows the results of comparative oxidation tests on K-42-B, commercial nickel, 18-8 stainless steel and 80-20 nickel-chromium alloys. The latter two are

Fig. 3 — A Red-Hot Bell Cast of K-42-B Gives a Sustained Full Note; a Steel Bell a Dull Thud



well known and much used because of their resistance to oxidation at high temperatures. In two years in air at 1112° F. (600° C.), a low red heat, K-42-B showed no more than a greenish tarnish and no scale formation. These results show K-42-B to be comparable to 80-20 nickel-chromium, which is among the best of known alloys so far as resistance to oxidation is concerned.

Corrosion Resistance — K-42-B appears to be immune to atmospheric corrosion under indoor laboratory conditions. On exposure for two months to dripping warm Pittsburgh tap water a machined but not polished surface showed visible attack. In another test a 0.005-in. strip of cold rolled and age hardened material was subjected for six weeks to intermittent immersion in synthetic sea water on a 30-min. cycle, while in contact with rubber bands and tinned iron paper clips. Very slight corrosion appeared at those points where it was directly in contact with the foreign materials; on the whole the attack was surprisingly small and did not even approach perforation of the 0.005-in. specimen.

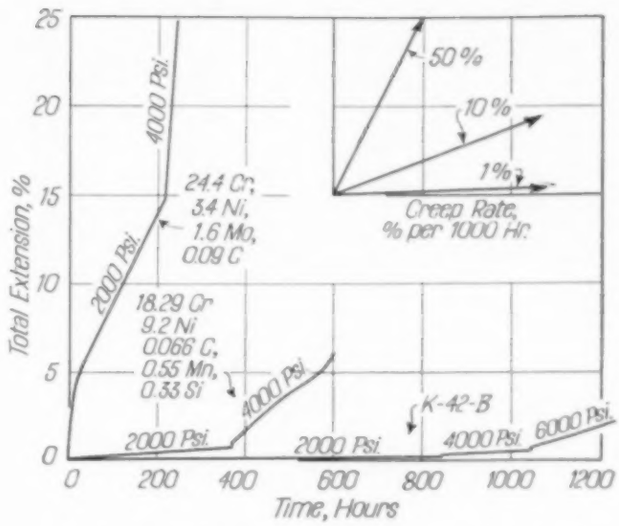


Fig. 4 — Creep Tests at 800° C. (1472° F.) on Two Commercial "Stainless" Steels and K-42-B

Oxidation Tests in Air at 800° C. (1472° F.)

Alloy	100 Hours			200 Hours			400 Hours		
	Gain	Loss	Oxide*	Gain	Loss	Oxide*	Gain	Loss	Oxide*
80-20 Ni-Cr	0.017		c. a.	0.022		c. a.	0.025		c. a.
K-42-B	0.016		c. a.	0.021		c. a.	0.025		c. a.
Nickel	0.084		c. a.	0.120		c. a.	0.171		c. a.
18-8		0.085	c. s.		0.215	c. s.		0.342	c. s.

*c. a. — completely adherent; c. s. — completely scaled.

Such qualitative observations as have been made in the laboratory indicate an order of corrosion resistance possibly superior to that of the better classes of 18-8 alloy.

Accelerated corrosion tests were performed by C. R. Austin and published in Technical Paper 29 of Pennsylvania State College, Mineral Industries Experiment Station. He used an intermittent immersion method similar to that described by Rawdon and Krynitzky in *Proceedings* A.S.T.M., 1924-II, with modifications which gave good temperature control. Normal HCl (36.5 g. per liter) and HNO_3 (63 g. per liter) were used with an immersion cycle of 1 min. in the acid and 1 min. suspended in air.

The specimens were in the form of 2-in. lengths of round, hot rolled bar stock, sand blasted to give uniformity of initial surface conditions. The specimens were supported by glass hooks and given a preliminary test for 24 hr. Samples were then removed, washed, dried and weighed. Succeed-

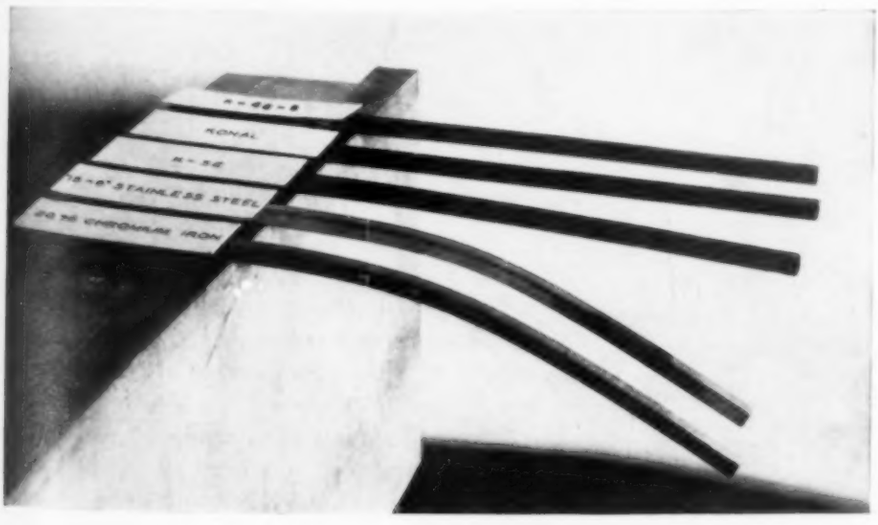


Fig. 5 — Three Alloys of the K-42-B Family Are Straight After 30 Hr. at 2350° F., Whereas 18-8 and 20% Cr-Fe Sag Under Own Weight

ing runs of 1, 2, 4, and 8 days were made with weighings in between.

The results are set forth in the table below, and suggest that K-42-B may be considered eligible for inclusion in the upper bracket of corrosion resistant materials.

Corrosion Resistance to Acid Solutions (Intermittent Immersion)

Alloy	Area Sq.Cm.	Total Weight Loss, Grams in					Total Loss, Per Sq.Cm.
		1 Day	1 Day	2 Days	4 Days	8 Days	
Tests in Normal Hydrochloric Acid							
K-42-B	20.2	0.130	0.105	0.160	0.356	0.752	0.0743
Nickel	22.2	0.364	0.271	0.375	0.723	1.351	0.138
80-20 Ni-Cr	18.0	0.217	0.216	0.377	0.774	1.545	0.178
Tests in Normal Nitric Acid							
K-42-B	20.2	0.150	0.004	0.000	0.000	0.005	0.0078
Nickel	22.2	0.514	0.202	0.293	0.482	1.055	0.115
80-20 Ni-Cr	18.0	0.386	0.010	0.002	0.001	0.004	0.022

Electrical Characteristics — K-42-B may be classed as a high resistivity alloy. Figure 6 notes its electrical resistivity in various heat treated conditions, as well as the effects of certain temperature cycles.

Magnetic Properties — At room temperatures and above, K-42-B is practically non-magnetic. In liquid air, —182° C., it is somewhat magnetic — that is, a definite pull can be felt when a strong magnet is brought close. However, the permeability is quite low, being about 1.008 at 0° C., 1.014 at —100° C., and 1.07 at —195° C.

Thermal Expansion — In high temperature work dimensional changes due to stress are not the only source of trouble. Thermal expansion often plays an important part by causing difficulties in fits or clearances, and also by creating stresses in restrained parts that sometimes cause permanent alterations of shape and a train of attendant troubles.

Figure 7 shows an expansivity test on a specimen of K-42-B taken from hot rolled bar stock. The thermal cycle was as follows:

1. Heating to 950° C. in 1½ hr.
2. Hold at 950° C. for 1 hr.
3. Cooling to 465° C. in 4 min.
4. Reheat to 600° C. in 7 min.
5. Hold at 600° C. for 16 hr.
6. Cooling to room temperature in 4 hr.

The effects of solution and precipitation reactions in the microstructure are shown by the fact that the curve for rapid cooling from 950° C. follows a different course from the curve for slow heating.

On reheating from 465 to 600° C. during 7 min., a contraction of about 1.67 parts per thousand (or 0.00167 in. per in.) due to constitutional changes was partly counteracted by expansion. Apparently no appreciable dimensional changes due to constitutional changes occurred during the ensuing 16 hr. of stationary temperature, and from 600° C. down, the heating and cooling curves coincided closely. Mean values for the normal expansion coefficients are given just above.

Temperature Range, ° C.	Expansivity Parts per Million
50 to 200	14.00
50 to 300	14.40
50 to 400	14.85
50 to 500	15.10
50 to 600	16.17
500 to 600	17.40

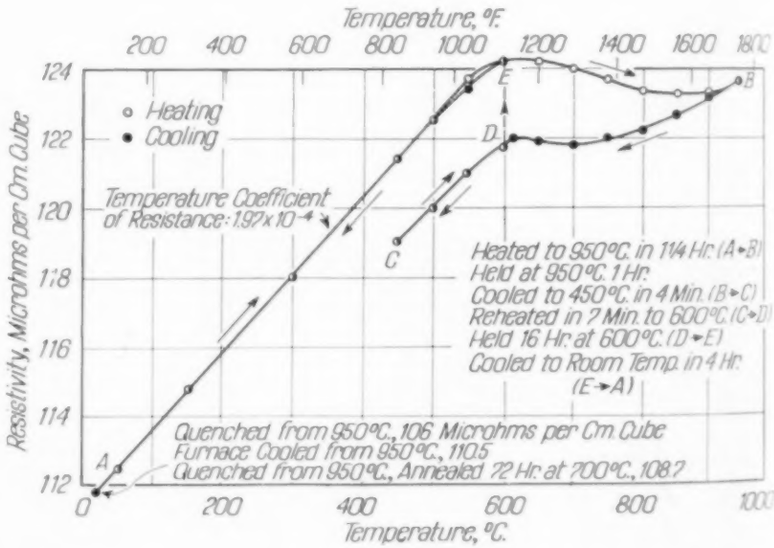


Fig. 6 — Measurements Show K-42-B Is a High Resistivity Alloy

The foregoing results indicate that the expansivity of K-42-B is somewhat higher than ordinary steels up to approximately 700° C. and approximately the same as that of the austenitic alloys of the 18-8 type. Dimensional changes due to constitutional effects appear to be relatively small and are evidenced by an expansion during cooling, which tends to minimize internal

stress set up during quenching from the upper range of temperature.

Expansivity curves of two low-manganese experimental steels are included in Fig. 6 for comparison, with particular reference to irreversible dimensional changes occurring in similar commercial materials. It will be seen that these changes in the steels are much larger and of opposite sign.

Making and Shaping — K-42-B is made in electric furnaces, either arc or induction, and may be cast to form special shapes or into ingots and subsequently forged and hot and cold rolled to the usual commercial shapes.

Machining properties of wrought and quenched K-42-B are similar to those of stainless steels of the 18-8 type. Slower speeds and lighter cuts are necessary than with carbon steels. However, the difficulties are no more than would be expected of any ductile material of the same strength.

As-cast the material can be machined only with difficulty; drilling is usually impracticable. However, by reheating to approximately 1800° F. (950° C.), quenching in a salt bath held at approximately 925° F. (500° C.) and air cooling, machinability may be improved even in quite large sections to correspond with that of the wrought material as quenched.

A collection of cast, wrought, hot rolled, cold rolled, and machined shapes are photographed in the tail piece of this article.

Heat Treatment — K-42-B responds to heat treatment. A usual procedure is to quench from the range between 950 and 1100° C. (1650 and 2000° F.) and "temper harden" by reheating a few days between 500 and 700° C. (950 and 1300° F.). Further improvement in mechanical properties can be made by cold rolling before or after quenching or both.

A general idea of the response to heat treatment and cold work is given by Fig. 8, page 360.

The long time and high temperature required for "temper hardening" suggest that the high temperature properties of K-42-B are relatively stable.

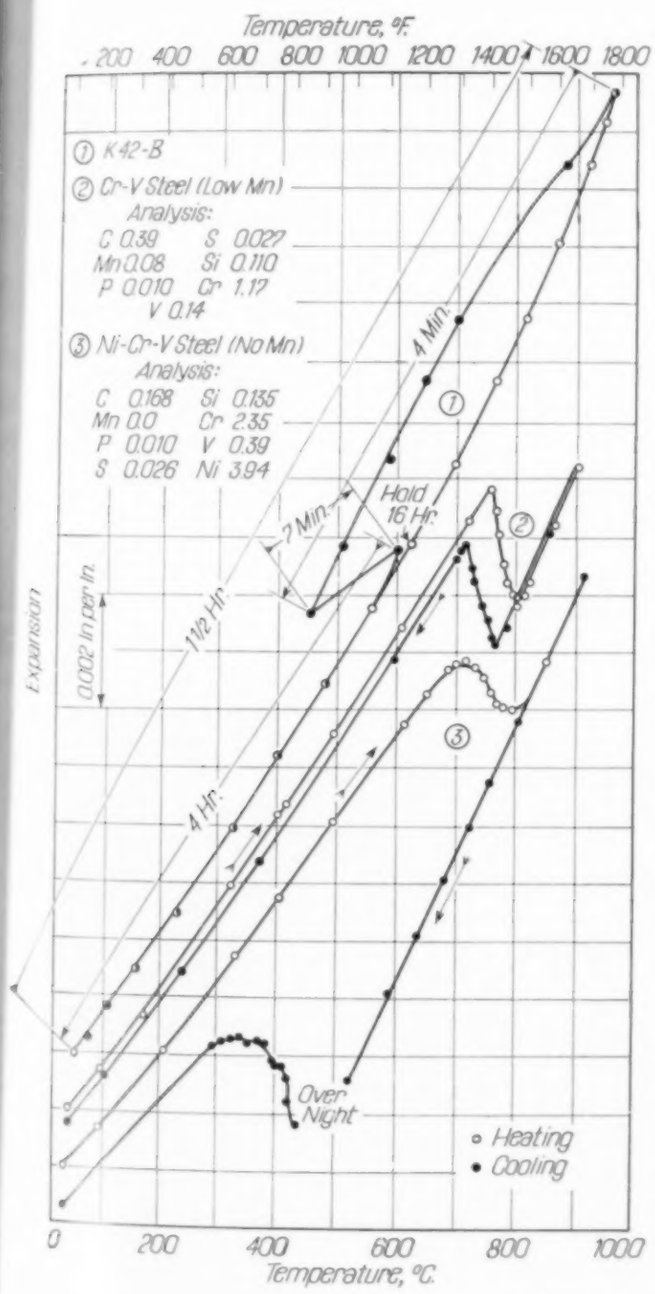


Fig. 7 — Thermal Expansivity of Comparative Alloys, Showing Especially Opposite Nature of Dimensional Changes in K-42-B on Cooling From About 900° C. Curves for special steels from Scientific Paper No. 433, National Bureau of Standards

Applications

While it is a little early to state the ultimate utility of the alloy, K-42-B may, broadly speaking, be applicable wherever there is a need for high strength, together with good resistance to corrosion and oxidation. Frequently a small part will determine the size or net performance of a costly assemblage. Considerable expense is then justified in order to apply materials having special capabilities. It would seem that K-42-B will find its more important applications in the form of such critical parts rather than as a tonnage material.

Nearly all modern designs aim to avoid high stresses in hot parts. Reasonably good balance among design features is struck with

conventional materials by limiting the operating temperatures and stresses. In such cases mere substitution of material usually yields less than maximum advantages. Perhaps K-42-B may be looked upon, not as a substitute material, but as one on which to base new designs which, by taking full advantage of the properties of the new material, will make possible the accomplishment of new things.

K-42-B has been successfully applied in competition with other materials for hangers for resistors in electric furnaces operating with hydrogen atmosphere at 1250° C. (2250° F.), for extrusion cylinders running at 600 to 650° C. (1100 to 1200° F.) with internal pressures of 100,000 psi. or more, in making extruded metal shapes, for garter springs for shaft seals in steam turbines, for tongs and carriers in heat treating furnaces, and for non-sputtering electrodes in thermionic devices.

In the high pressure steam field it would seem applicable as springs, valve bodies, stems, seats and other high pressure steam control parts, as well as turbine blading and cylinder bolts.

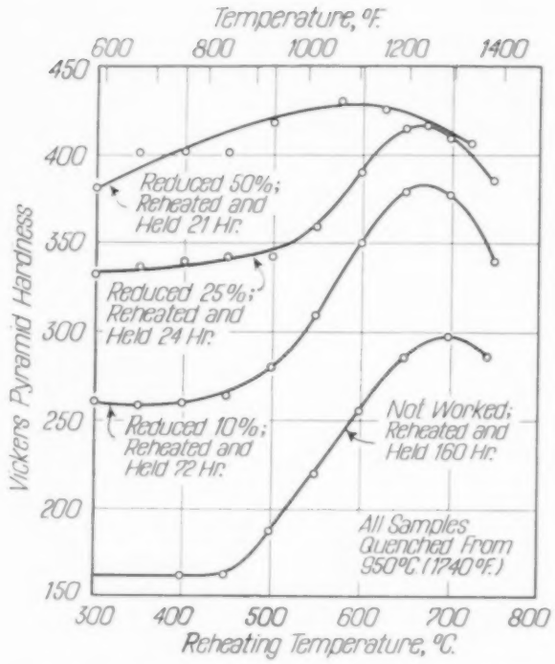


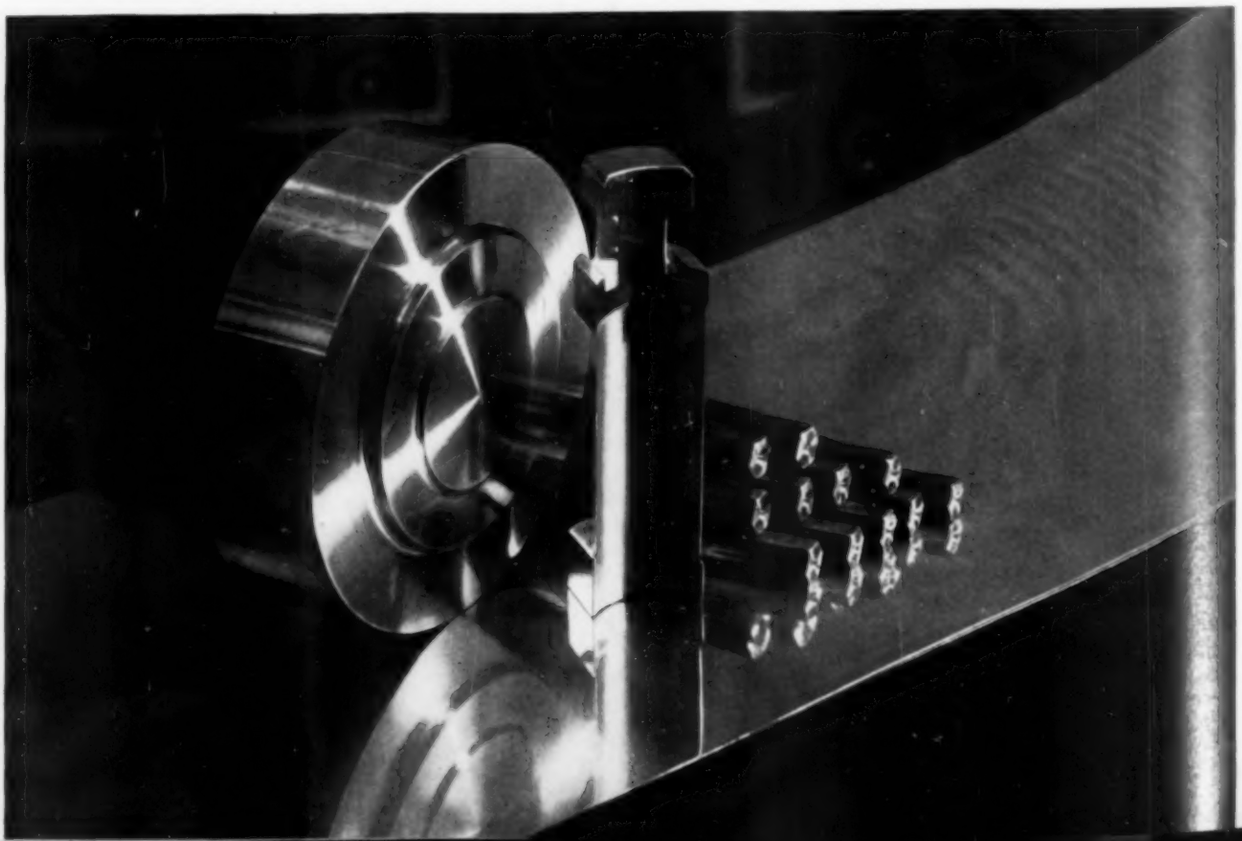
Fig. 8 — Hardness After Quenching From 950° C. (1740° F.), Cold Rolling Various Amounts, and Holding at Various "Temper Hardening" Temperatures for Times as Noted

Valves, exhaust manifolding, spark plug points, cylinder head bolts and supercharger turbine rotors for internal combustion engines may be locations where K-42-B could be used to advantage in engines which perform under most severe overloads.

In industrial heating furnaces such parts as work supports, conveyor parts, mesh belts, rollers, pins, and other mechanical or structural elements that must operate under stress at high temperatures offer openings for K-42-B.

Gas turbines are still in the development stage, and it would seem relatively easy to make departures in design to take advantage of new materials. Temperatures ranging from 500 to perhaps 800° C. (900 to 1500° F.) are contemplated, and K-42-B appears to be a promising material for blading, shafting, valve parts, bolts and possibly even such major elements as rotors and cylinders.

Collection of Cast, Wrought, Hot Rolled, Cold Rolled, and Machined Shapes of K-42-B



Correspondence and Foreign Letters

Saving Nickel in High Alloy Castings

NICETOWN, PHILADELPHIA

To the Readers of METAL PROGRESS:

In his article in the January issue on "True Economy in the Use of Chromium and Nickel", MATTHEW A. HUNTER, I am afraid, puts some suggestions made in reports of the Alloy Casting Institute into words of his own, and thus puts the Institute in the wrong light.

Merely to set the record straight, the document to which he referred is entitled "A Report of the Alloy Casting Institute on Possible Saving of Nickel in the Alloy Casting Industry", and was addressed at his request to ZAY JEFFRIES, chairman of the Metals Conservation & Substitution Group of the National Academy of Sciences. It was circulated to all producers of alloy castings for their opinions prior to submission to the Office of Production Management.

The figures given in the report were for the year 1940. It was suggested in the report that, in the interest of nickel conservation, some castings that had been made of 60 to 70% nickel grade might be made of the 35 to 40% nickel alloy, and some of those made of the 35 to 40% nickel alloy might be made of the 25% chromium, 12% nickel alloy, and so forth. It was then shown that, had this sort of substitution been applied in three-quarters of the 1940 production, a saving of 1,000,000 lb. of nickel and an increase in consumption of 500,000 lb. of chromium would have resulted for that year.

It was estimated that production in 1941 of heat resistant castings might be double that of 1940 and that, even were the suggested substitutions found possible, 5,360,000 lb. of nickel would be required for heat resisting castings. Actually 5,268,200 lb. of nickel was used in such castings in 1941. Furthermore the Institute's estimate for nickel consumption in corrosion resisting castings for 1941 was 840,000 lb. against an actual 822,300.

Available figures can also be analyzed as to types and grades. For instance, the production of 60 to 68% nickel castings in 1941, the year just completed, required the consumption of 1,350,900 lb. of nickel. Had the production of such castings in 1941 borne the same relationship to total alloy castings produced that it did in 1940, the nickel requirement would have been 2,215,200 lb. Thus a sizable saving in strategic metal *was* made. The Institute did not suggest, as Professor HUNTER's text states, that 500,000 lb. of the 60% alloy would meet our annual requirements. Figures were available at the time of writing the original report for the first four months of 1941, and production of castings containing 60 to 70% nickel already had amounted to 624,000 lb. While production was even then on the increase the proportion of higher nickel alloy being cast was already declining and it continued to do so.

While the general recommendation was made that lower nickel alloys be used wherever possible in place of high nickel alloys, there was a warning that such substitutions should not be carried to the extent of causing frequent replacements and lengthy shut-downs.

The supplementary report requested by H. LEROY WHITNEY, of OPM, detailed to some extent the types of alloys suitable to various conditions of service. It carried the following warning with respect to substitution:

"Any arbitrary limiting of the percentage of nickel which would tend to force, willy-nilly, the

substitution of one of these types for another, might well result in a dislocation of industrial practice detrimental to the defense program and result in waste rather than conservation of nickel."

Professor HUNTER seems most interested in supporting the higher nickel type of heat resisting alloy (60% nickel). What the Alloy Casting Industry's supplementary report to Mr. WHITNEY of OPM contained, concerning this high nickel type of alloy, was:

"There are some applications which cannot be generally classified, however, where 60 or 65% nickel alloy is the only suitable material, or is clearly metallurgically indicated, and it is practicable for the producer to certify the necessity for such use of this class of alloy."

What Committee B-4 of the American Society for Testing Materials said in its report concerning the high nickel alloy was:

"Furthermore, in this field there are cases where particularly severe service conditions must be met and where it has been well established that alloys of higher nickel contents provide the most economical use of that metal. Where proof of such circumstances is submitted, we recommend that the producer be permitted to furnish alloys containing nickel up to 62%."

These facts and quotations are sufficient, I think, to show that both the Alloy Casting Institute, Committee B-4 of A.S.T.M., and Professor HUNTER agree that there should be no arbitrary substitution of alloys lean in nickel for rich ones, and that all of us realize that nickel and chromium are present because of their specific effect in resisting certain types of chemical attack. None of us have ever questioned the usefulness of the 60% nickel type.

FRANCIS B. FOLEY
Chairman of Technical Committee
Alloy Casting Institute

Railroad Failures
The Question of "Burned" Axles

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

In the article on "Railroad Failures in Tracks and Cars" by Messrs. MCBRIAN and ARCHIBALD in the August issue of METAL PROGRESS, it is suggested that actual "burning" of the steel had occurred in the axle which failed as a result of a hot box.

We in these laboratories have examined failures of this type, and have on several occasions found interpenetration of bearing metal and heating of the axle journal through the critical range, but never burning. In fact, our findings have been so similar to those shown by the illustrations in the article that we are in no doubt that interpenetration of bearing metal had occurred in the axle reported by Messrs. MCBRIAN and ARCHIBALD, and not burning.

J. H. SLAGG
Metallographist
English Steel Corp., Ltd.

Mr. McBrian's Reply

As we read Mr. SLAGG's comments, his criticism is directed at our use of the term "burning". May we say at the outset that this is the term used commonly by railroad men to

Overheated Steel Axle, at 200 Diameters, Showing Evidences of "Burning", or Incipient Melting at Austenite Grain Boundaries

describe failures of this type in connection with railroad car axles. A more scientific definition of the term is by HOWE, quoted in SAUVEUR's "Metallography and Heat Treatment of Iron and Steel" to the effect that burning is "a mechanical separation of the grains on extreme overheating". STOUGHTON & BUTTS in "Engineering Metallurgy" call burning "a heating to above the solidus line".

We feel justified in saying that burning in the strict metallurgical sense is encountered not infrequently in the failures of American railroad car axles. The accompanying photomicrograph, from many in our files of failures, is unquestionably an example which fits the definitions of burning as quoted, as does the one in our article.

R. McB.

Influence of the Electronic Structure of Soluble Elements on the Range of Stability of Gamma Iron

SCHENECTADY, N. Y.

To the Readers of METAL PROGRESS:

The influence of various elements on the range of stability of α and γ phases in iron has had practical and theoretical interest for metallurgy for many years. Certain elements tend to decrease the temperature range of γ phase (in pure iron 1663 to 2550° F.) and eliminate it entirely at a certain characteristic composition. Others have the opposite influence of increasing that range. We are interested here only in those elements which are soluble in iron. The practical importance of these phenomena and the need for correlation with other properties of elements, especially for study of ternary alloys, does not need to be stressed.

The first attempt to explain these facts was made by ORMOND as early as 1890, and then by WEVER, who tried to correlate them using the atomic-volume curve. The result of these and other considerations was the statement that there is a connection between the position of the element in the periodic system and its influence on the relative stability of the two phases. This is shown in the attached figure. Full circles indicate elements which, added to iron, decrease the range of stability of the γ phase; full triangles indicate elements having the opposite influence. Open circles and triangles indicate elements of limited solubility in iron but showing a distinct influence on the two transformation points.

A new interpretation of these known phenomena was suggested by the undersigned at the meeting of the American Physical Society in Princeton last December. Results of the modern theory of electronic structure of atoms indicate that there is a connection between the density of the so-called "free electrons" in certain metals and their energy. We need not go here into details which will be given elsewhere; it may be said, however, that according to the theory an increase in the number of electrons per iron atom increases the stability of the γ phase and decreases the stability of the α phase. In the periodic table, elements in each column have similar outer electronic shells, and the number of electrons in these shells increases toward the right side of the table. This explains the most evident distinction between the elements to the left of the iron column and those to the right of it. The group of atoms to the left of iron that have fewer outer electrons than iron decrease the average number of electrons per atom in the alloy and thus, according to the result mentioned above, *increase* the range of stability of the α phase. The opposite happens for the other small group of elements to the right of iron.

This obviously does not explain the influence of *all* elements on the allotropy of iron as, for instance, manganese, which is to the left of iron, and carbon and nitrogen as well as copper and zinc. In order to take these into account, we have to consider not only the number of electrons in the atom of the alloying element but also the energy necessary to transfer the electrons to the corresponding levels (bands) of the iron lattice. Such an estimate can be carried out for these elements on the basis of our knowledge of the optical terms of free atoms.

In this way, taking into account both the number of electrons and the energy involved, all but carbon and nitrogen are satisfactorily explained. The analysis of the electronic structure of these two alloy systems is more

Wever's Diagram Showing the Connection Between the α⇆γ Transformation in Iron and the Periodic Table of Chemical Elements. (Minor changes are due to recent data.)

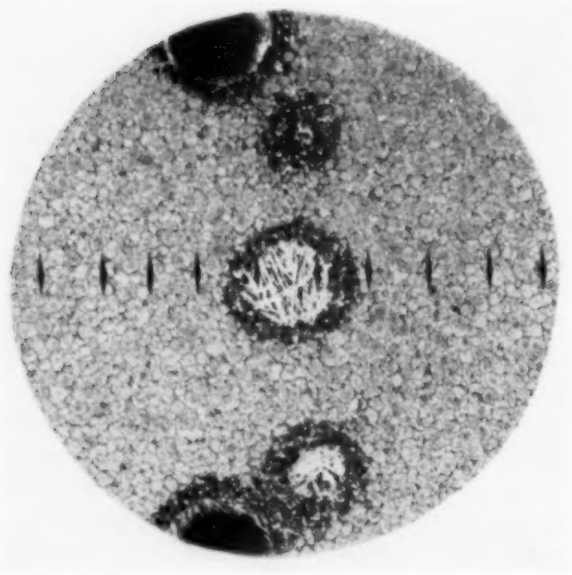
	I		II		III		IV		V		VI		VII		VIII			
I														H				He
II	Li x		Be ●			B ○		C △		N △		O ○?		F				Ne
III	Na x		Mg x			Al ●		Si ●		P ●		S ○?		Cl				Ar
IV	K x		Ca x		Sc		Ti ●		V ●		Cr ●		Mn ▲		Fe	Co ▲	Ni ▲	
		Cu △		Zn △?		Ga		Ge ●		As ●		Se		Br				Kr
V	Rb x		Sr x		Y		Zr ○		Cb ●?		Mo ●		Ma		Ru ▲	Rh ▲	Pd ▲	
		Ag x		Cd x		In		Sn ●		Sb ●		Te		J				x
VI	Cs x		Ba x		Ce ○		Hf		Ta ○		W ●		Re ●?		Os ▲	Ir ▲	Pt ▲	
		Au △		Hg x		Tl x		Pb x		Bi x		Po						Rn
VII			Ra x		Ac		Th		Pa		U							

● ○ Elements increasing stability of α-phase
▲ △ " " " " " γ-phase
x - " " insoluble in iron
Open symbols indicate limited solubility

difficult since they form an interstitial rather than substitutional lattice. It seems that here the role of the solute elements is merely to expand the iron lattice, and it can be shown that this lowers the energy of the γ phase relative to the α phase, and thus decreases the stability of the latter.

In some cases for which more detailed data are available, a more quantitative picture can be obtained in comparing the influence of various elements. Other properties, thermal and magnetic, are connected with the phenomenon here described, but their description goes beyond the limits of this note.

ROMAN SMOLUCHOWSKI
Research Laboratory
General Electric Co.



Micro-Hardness of Micro-Ingot

WAYNESBORO, PA.

To the Readers of METAL PROGRESS:

Above is a micrograph to add to your ever increasing collection of oddities.

The micrograph, taken at 100 diameters magnification, is that of a surface of 18-4-1 high speed steel which was experimentally treated as follows: Carburized at 1700° F. for 8 hr.; pretreated at 1750° F.; quenched in oil; hardened by preheating at 1550° F., superheating at 2350° F., and quenching in oil.

The word "experimentally" is used advisedly, since this treatment is hardly recommended for high speed steel! After treating the surface of the sample was lightly ground, polished and etched in 5% nital. The Rockwell hardness was C-46 and the specimen was *file hard*.

The central spot, dendritic in pattern, across which traverse the Knoop hardness indenter impressions, was liquid at the time the specimen was quenched from the 2350° heat. The spot or "pool" was originally just beneath what was a black oxidation pit such as may be seen near the edge of the micrograph. The average micro-hardness number of the two impressions inside the "pool" is 803, and the average micro-hardness number outside this area is 606.

The higher hardness in the "pool" area is possibly associated with the dendritic or quasi-martensitic structure. It is likely that the more rapid oxidation at the pit generated enough heat to melt the small drop, and reduced the carbon content of this area, and on quenching the metal did not retain the full austenitic structure of its surroundings.

J. G. MORRISON
Metallurgist
Landis Machine Co.

Welding Influences Philately

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

Some months ago we learned that the figure of a welder was adorning a new issue of stamps in the Union of South Africa, but have only recently been able to secure some samples. This special issue recognizes the great part arc welding is playing in the construction of all sorts of industrial and war equipment.

Each stamp is printed both in English and in Afrikaans, which is the case with all stamps issued in South Africa.

The stamp depicts a welder using modern shielded electric arc equipment and dressed in

protective head shield, gloves and other special clothing. The 6-penny stamp shown is of orange color. As far as I know, this is the first time that such a subject has been issued in the history of stamps.

ALTON F. DAVIS
Vice-President
Lincoln Electric Co.

Automotive exhaust manifolds must have resistance to growth, and good strength at elevated temperatures. Competitive conditions demand minimum costs.

An iron containing about 3.30% C — 2.20% Si — 0.70% Mn — 0.60% Cr — and 0.60% Mo does the trick, while holding down foundry and machining costs.

This Chromium-Molybdenum combination is characterized by high strength and toughness at the working temperatures encountered in exhaust manifolds. Its growth resistance prevents warpage and cracking — saves gaskets.

Send for our free technical book, "Molybdenum in Cast Iron," giving detailed data on Molybdenum irons of interest to production engineers and executives.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE—BRIQUETTES FOR THE CUPOLA • FERROMOLYBDENUM FOR THE LADLE

Climax Mo-lyb-den-um Company
500 Fifth Avenue • New York City

MOLY

Personals

A. L. Boegehold, chief metallurgist, General Motors Research Laboratories, Detroit, has been awarded the J. H. Whiting Gold Medal of the A.F.A., and **John E. Galvin**, president, Ohio Steel Foundry Co., Lima, Ohio, will receive the John A. Penton Gold Medal of the A.F.A.

Robb W. James and **G. J. Hales**, formerly lieutenants in the Cleveland Ordnance District, have been promoted to the rank of captain.

Monte E. Parker of Edison Vocational School, Seattle, Wash., secretary-treasurer of the Puget Sound Chapter, has been granted a lieutenant commander's commission in the Navy in the field of metals, with a tentative assignment to Charleston, S. C.

Transferred by Lindberg Engineering Co.: **W. R. Smith** from the Chicago sales to the Detroit sales office.

Carey Pruitt is on leave of absence from the Carnegie-Illinois Steel Corp., and is a first lieutenant now stationed at Watertown Arsenal.

W. D. Riddle, Jr., formerly metallurgist at Republic Steel Corp., Chicago, is at present metallurgist for American Forge Co., Berkeley, Calif.

Transferred: **Stanley C. Johnson**, from Clairton Works of Carnegie-Illinois Steel Corp. to U. S. Steel Corp. Research Laboratories, at Kearny, N. J.

Roy J. McDaniel is now employed as a principal physical science aid in the engineering department of the U. S. Naval Air Station, Norfolk, Va.

W. C. Heaslip has been transferred from United Steel Corp., Ltd., Welland, Ont., to the New Castle Defense plant, Division of Edge Moor Iron Works, Inc., New Castle, Del., as chief metallurgist and general superintendent in charge of all operations.

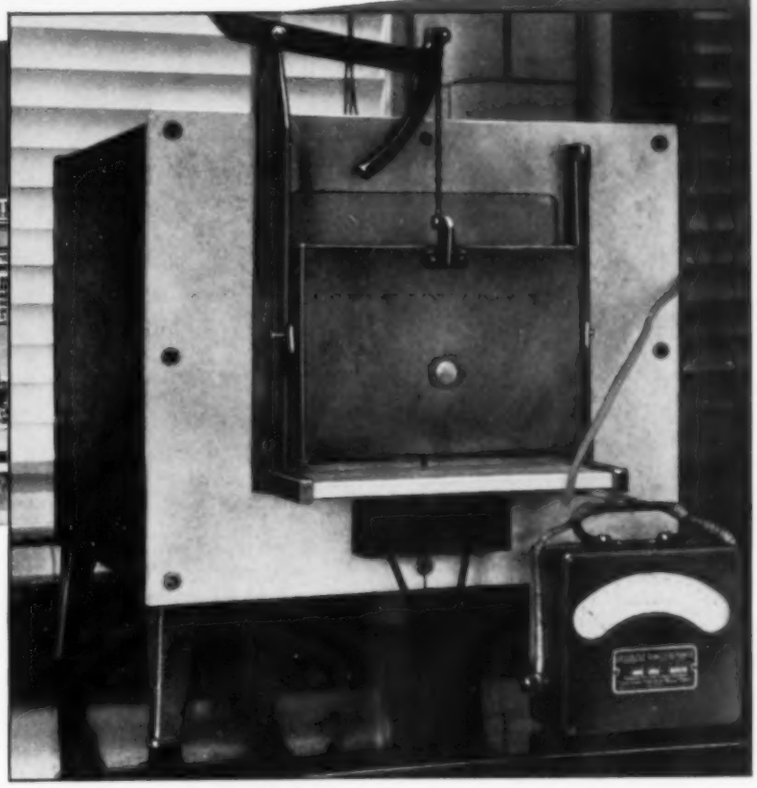
Bertrand S. Norris is now an instructor in the Department of Metallurgy, Pennsylvania State College.

Capt. **Joseph L. Jones** is now officer in charge of inspection for the Ordnance Department and also in charge of production control at the St. Louis Ordnance Plant.

James Brinn has accepted a position as plant superintendent with the Northwestern Iron and Metal Co., Lincoln, Neb.

Theodore E. Wood, formerly design engineer for David Bradley Mfg. Works, is now employed by the Elliott Co. of Jeannette, Pa., as an experimental engineer.

NEITHER MAN KNEW!



When Thos. A. Edison made his basic electrical discoveries, he likely did not comprehend their full significance. When A. L. Marsh invented the series of Chromel (nickel-chromium) alloys for the fields of electric heat and pyrometry, he, too, could not foresee the extent of their value. But every passing year of the past 35 has shown the value of these Chromel alloys to home and industry. Chromel made possible most electric furnaces in use today. Thus, it placed this Hoskins laboratory furnace in the Edison Institute at Dearborn, Michigan. Chromel also has placed many Hoskins electric furnaces in the Ford factory. If you need an electric furnace for your laboratory, or for production heat-treatment, ask us for Catalog 58. . . . Hoskins Manufacturing Co., Detroit, Mich.

Our alloys are also available as heat-resisting castings. All the metals are melted by high-frequency induction, insuring purity and uniformity of analysis of the alloy. We specialize in alloys of the 35-15 type, as rolled rod or cast. If you need heat-resisting metal, tell us about it. We're sure we can help you.

HOSKINS PRODUCTS

ELECTRIC HEAT TREATING FURNACES • • HEATING ELEMENT ALLOYS • • THERMOCOUPLE AND LEAD WIRE • • PYROMETERS • • WELDING WIRE • • HEAT RESISTANT CASTINGS • • ENAMELING FIXTURES • • SPARK PLUG ELECTRODE WIRE • • SPECIAL ALLOYS OF NICKEL • • PROTECTION TUBES

HEATING ELEMENT WIRE — Chromel — NICKEL-CHROMIUM

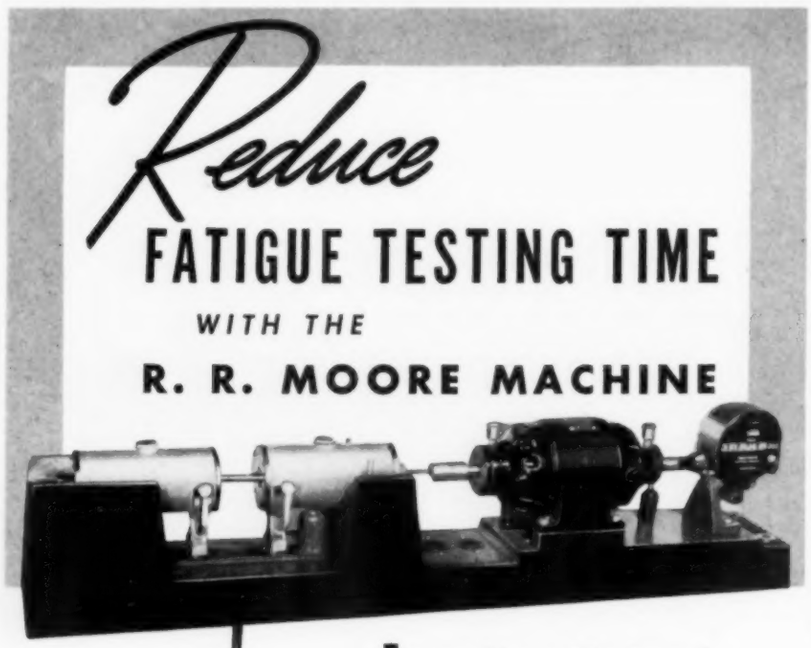
Personals

Ensign **Arthur E. Blirer**, U.S.N.R., is now stationed at the Naval Gun Factory, Washington, in the production division.

Stephen D. Garst is employed by the American Foundrymen's Association in Chicago as an assistant technical editor.

A. B. Lawrason, formerly with Railway & Power Engineering Corp., Ltd., Toronto, is now vice-president and general manager of The Eureka Planter Co., Ltd., Woodstock, Ont.

J. D. Lovely, formerly metallurgical engineer at Chrysler Corp.'s Highland Park Engineering Division, has been transferred to the Airtemp Division, Dayton, Ohio, as chief inspector.



Improved to meet the demands for rapid fatigue tests, the R. R. Moore high speed Fatigue Testing Machine now operates at speeds of 10,000 rpm. The machine is equipped with a variable speed drive—an essential feature in the testing of certain alloys which heat up when highly stressed and it also allows correlation of high speed tests with previous lower speed tests.

Based on the rotating beam principle, the R. R. Moore Machine has gained widespread acceptance. These fatigue testing machines are in constant use in the nation's leading research laboratories. Write for descriptive bulletin No. 134-A

Baldwin Southwark
DIVISION OF THE BALDWIN LOCOMOTIVE WORKS
PHILADELPHIA
BLW THE BALDWIN GROUP

John B. Flanagan, formerly with Great Lakes Steel Corp., is now employed in the process engineering department of the Pennsylvania Salt Mfg. Co. at Wyandotte, Mich.

A. C. Gunsaulus, formerly manager, mold design department, Goodyear Tire & Rubber Co., Akron, is now manager of development engineering, wheel and brake division, Goodyear Aircraft Corp.

Edward E. Jones, formerly inspector of engineering materials (aeronautical) at the Naval Aircraft Factory, Philadelphia, is now principal inspector of engineering materials (aeronautical) at the Bureau of Aeronautics, Navy Department, Washington.

Lars H. Nordenson has left Union Oil Co. of California and is now working for Tennessee Eastman Corp., Kingsport, Tenn., as a chemical engineer.

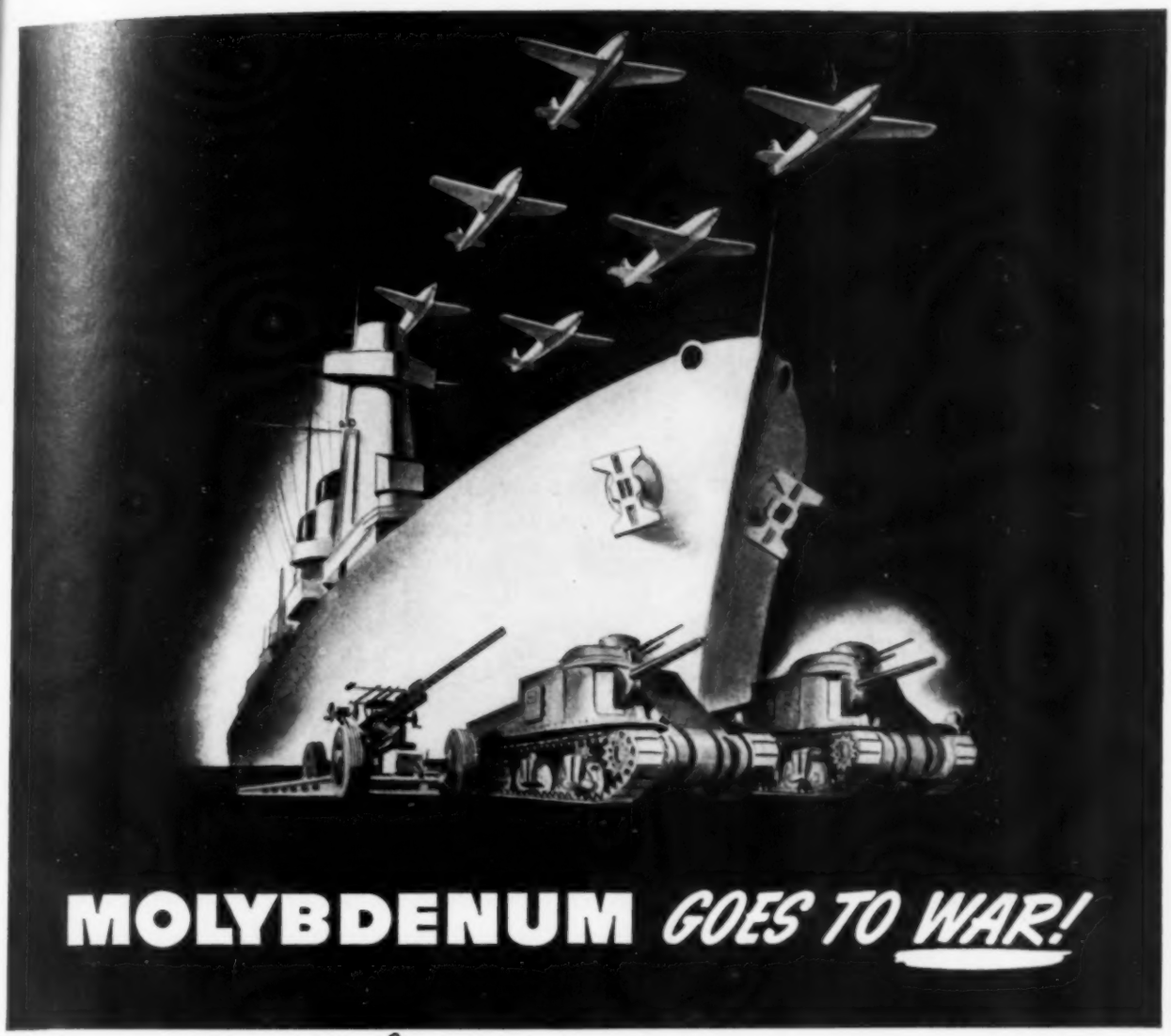
Nathaniel Fick, formerly in the metallurgical department of the Tennessee Coal, Iron and Railroad Co., has been transferred to the Gary Works, Carnegie-Illinois Steel Corp.

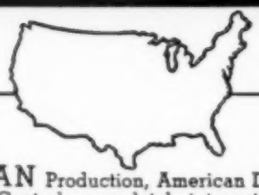
Floyd L. Wile, formerly heat treat inspector and metallographer, R. K. LeBlond Machine Tool Co., Cincinnati, is now inspector of ordnance materials, Cincinnati Ordnance District.

Carl Szego is now employed as superintendent at the Barth Smelting & Refining Works, Inc., Newark.

C. F. Wegner, formerly metallurgical foreman, Hudson Motor Car Co., is now heat treat foreman, Bendix Aviation Corp., Wayne Division, Plymouth, Mich.

W. P. Benter, formerly manager of the alloy steel bureau of Carnegie-Illinois Steel Corp., Pittsburgh District, is now chief metallurgist, Christy Park Works, National Tube Co., McKeesport, Pa.





AMERICAN Production, American Distribution, American Control—completely integrated.
Mines: Tucson, Arizona; Questa, New Mexico.
Smelting and Refining Works: York, Pa., Washington, Pa.
Offices and Warehouses: Pittsburgh, New York, Chicago, Detroit, Los Angeles, San Francisco, Seattle.
Sales Representatives: Edgar L. Fink, Detroit; H. C. Donaldson & Co., Los Angeles, San Francisco, Seattle.
Ample stocks, sales facilities, technical advice available.

Wherever American steel goes into weapons of attack or into defensive armor against the Axis powers, the importance of Molybdenum increases more and more.

High strength, uniformity of strength and hardness in irregular sections, high-temperature strength, machinability with high strength and high degrees of hardness—materials with such properties are the assurance of victory on land or sea or in the air. "Alloys will win the war."

No alloying agent is more versatile than Molybdenum, none more easily introduced in various compositions for various needs. And none is more tolerant in the presence of other elements, conferring its own benefits without diminishing theirs.

In the United States, and nowhere else, Molybdenum is abundant. Some metallurgical materials of great value become scarce under war demands, but of Molybdenum there is still enough for both military and civilian uses. Correct advice and convenient supplies are offered to any American manufacturer. Literature will be mailed on request.

MCA

MOLYBDENUM CORPORATION OF AMERICA
GRANT BUILDING, PITTSBURGH, PA.

Personals

Ensign **Philip L. Kirsh**, U. S. N. R., is on temporary duty as ordnance inspector at the General Electric Co. in Schenectady.

Ralph Parkman is now working in the metallurgical laboratory of the Halcomb Steel Division of the Crucible Steel Co. of America.

Robert F. Yeager, formerly instructor of chemistry and metallurgy at Fenn College in Cleveland, is now working at the Bureau of Mines, Mineral Economics Division, Secondary Metals Section in Pittsburgh.

Henry J. Becker has resigned from Sperry Gyroscope Co., Garden City, N. Y., and is now associated with the Goodyear Aircraft Corp., Akron, Ohio, assisting in tool engineering.

Your
METAL CLEANING Problems
Are Solved Here
ENGINEERS who think in terms of metal cleaning . . . skilled chemists . . . production men with years of experience in building metal cleaning equipment . . . all comprise the Detroit Rex organization. All of them are at your service.
They have been responsible for some of the most important developments in metal cleaning processes. Today in Detrex drafting rooms, machines are being designed for even faster, more efficient production. In Detrex laboratories, constant progress is being made in developing the most effective cleaning compounds and solvents. In Detrex factories, machines are being built to give you years of trouble-free service.
• Above: One of the several Detrex drafting rooms
• Center: A view through one of the Detrex factories
• Below: Two of the modern laboratories in the main Detrex plant
SOLVENT DEGREASING and ALKALI CLEANING
DETROIT REX PRODUCTS COMPANY
13006 HILLVIEW AVENUE • DETROIT, MICHIGAN
Branch Offices in Principal Cities of U. S. A.—In Canada: Canadian Hanson & Van Winkle Co., Ltd., Toronto, Ontario

Major **Leslie S. Fletcher** of Watertown Arsenal has been promoted to the rank of lieutenant colonel.

L. W. Oswald has been appointed manager, Bar and Semi-Finished Materials Bureau, Carnegie-Illinois Steel Corp., Metallurgical Division, Pittsburgh District.

E. K. Smith, formerly service metallurgist for the Electro Metallurgical Co., Detroit, has been given leave of absence for the duration and is now senior metallurgist, Industrial Service, Tank and Combat Vehicle Division, Army Ordnance Department, Washington, D. C. His wife, **Rebecca H. Smith** has given up her office for metallurgical work in Detroit to take up similar work at Naval Gun Factory, Navy Yard, Washington.

Harold R. Wegner, formerly metallurgist with Brown-Lipe-Chapin Division of General Motors Corp., Syracuse, has resigned to accept the position of metallurgist and plant superintendent with Syracuse Heat Treating Corp.

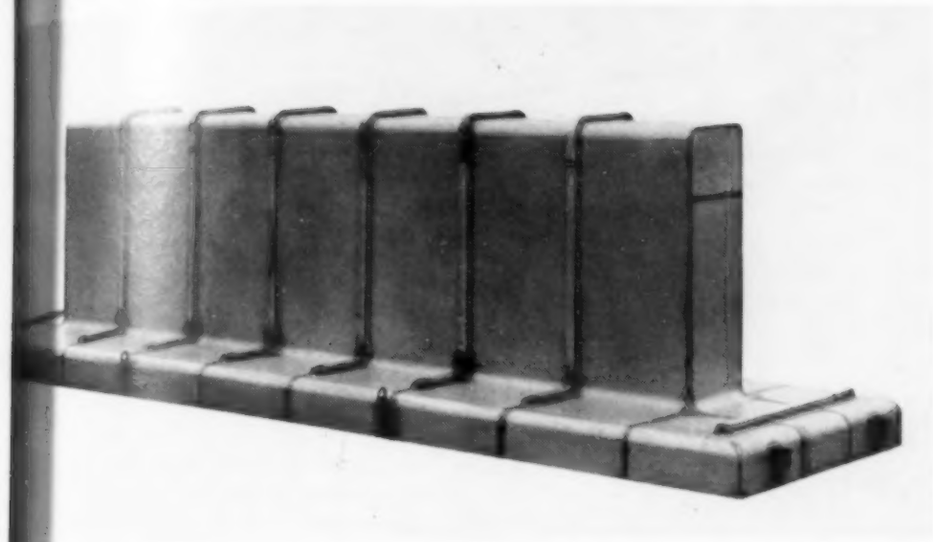
Promoted by Carnegie-Illinois Steel Corp.: **Frank T. Bumbaugh**, from metallurgical engineer, bar and semi-finished products in Pittsburgh, to assistant manager of sales, alloy division, Chicago.

William E. Butts, vice-president, General Metals Corp., Oakland, Calif., has been appointed to the Steel Casting Industry Advisory Committee of the War Production Board.

Robert P. Lawrance has been made chief metallurgist at the plant of the National Enameling & Stamping Co. of Jacksonville, Ill.

Arthur Durr, after several months' service as development engineer, Malleable Founders Society, has returned to Eastern Malleable Iron Co. as technical advisor.

WE SPECIALIZE IN THE FABRICATION AND WELDING OF ALL TYPES OF ALLOYS

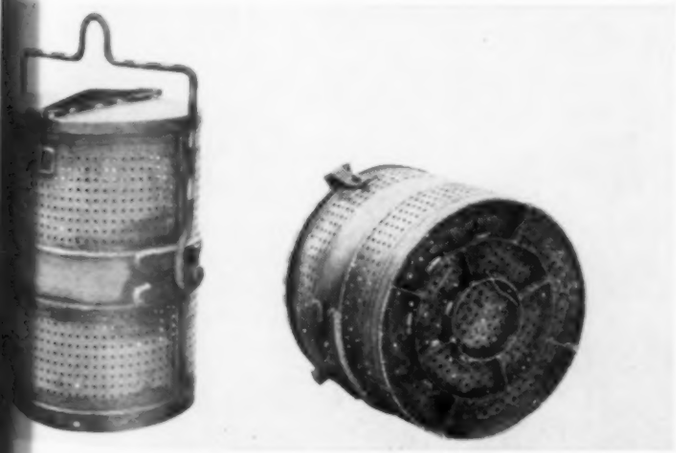


Annealing Cover produced for a large steel mill. Our special process welding gives this annealing cover unusual strength.

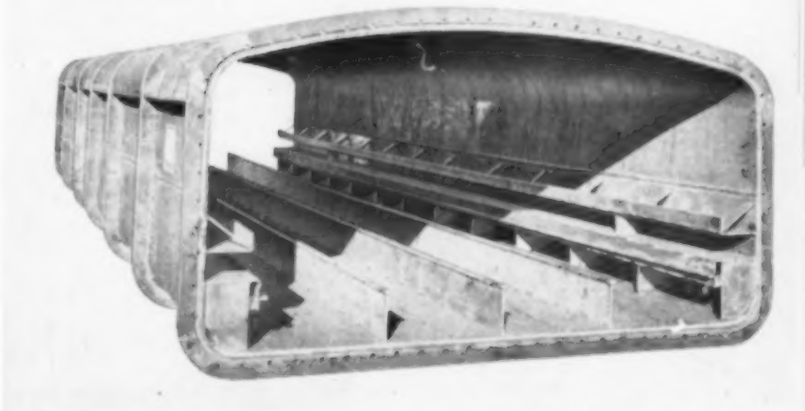
Here are just a few of the many products made by The Pressed Steel Company. Manufacturers everywhere have been able to affect substantial savings through the use of this lightweight equipment . . . savings that mean increased production and added profits.

Annealing Tubes made to specification. They are 20 ft. long. Made of lightweight alloy. Tubes like this have been in use for over 10,000 hours and still going strong.

Bubble Caps for Refinery fractionating equipment. 75% lighter. Pressed Steel Company caps are heated **after** fabrication.



Pickling Basket made of type 304 stainless steel. Special alloy welded.



Cross section view of **Alloy Retort** weighing 5400 lbs. Special inside construction to specification.

THE PRESSED STEEL COMPANY

of WILKES-BARRE, PENNSYLVANIA

BRANCH OFFICES: 337 Curtis Bldg., Detroit; 1914 Vermont Ave., Toledo; 205 Engineers Bldg., Chicago; 254 W. 31st St., New York

PRESSED STEEL COMPANY PRODUCTS: Carburizing and Annealing Boxes, Thermocouple Protection Tubes, Seamless Steel Cylinder Caps, Seamless Steel Neck Rings, Welded Alloy Tubing for High Temperature and Corrosive Application

Personals

Promoted: **Howard S. Riley**, from assistant superintendent to superintendent in charge of production for Warren Steam Pump Co., Warren, Mass.

Ordered to active duty in the U. S. Army: **Howard C. Beede**, as first lieutenant in the Coast Artillery Corps; **G. Park Boian**, assigned to the Cincinnati Ordnance District; **John J. Grimes**, with the Air Corps in the Central Procurement District, Detroit.

John L. Brewster, formerly engaged on Priority Section work for General Electric Co. in Bridgeport, Conn., is now studying the Naval Reserve Midshipmen's Engineer Training Course at Annapolis, leading to a commission as ensign in the U. S. Naval Reserve.

Lieut. **Karl Wentzel**, U. S. N. R., is now an engineer officer on a minesweeper somewhere in the Atlantic.

L. J. Haga has given up his professorship at Illinois Institute of Chicago to become connected with the Kaydon Engineering Corp. of Muskegon, Mich.

Transferred by Pittsburgh Steel Co.: **C. J. Gaspar**, from Chicago as special representative, Stainless Steel Division, to the general office in Pittsburgh as assistant manager of stainless steel sales.

H. S. Van Vleet of the American Can Co. is now connected with the Materials Conservation and Substitution Branch of the Bureau of Industrial Conservation at Washington, D. C.

Roger Waindle, sales manager, The Fahralloy Co., has been released to the Chicago Ordnance District of the War Department.

A. B. Albree has received a leave of absence for the duration from Wetherell Bros. Co. in Cambridge, Mass., and is now employed by the Bridgeport Grinding Machine Co., West Haven, Conn., as buyer and metallurgist.

James A. Harding, formerly factory manager with Simplex Valve & Meter Co., Philadelphia, is now manufacturing engineer with Marchant Calculating Machine Co., Oakland, Calif.

Fred E. Bowman, formerly research fellow at Purdue University, is now research metallurgist at Climax Molybdenum Co. of Michigan.

H. B. Shepherd has been appointed assistant district sales manager of the Cleveland sales office of Jones & Laughlin Steel Corp. **L. S. Berkey**, formerly resident sales manager in Toledo, has been appointed district sales manager in St. Louis.

It Took
ELASTUF CHRO-MOLY
to Do THIS Job

This plunger operates in an automatic press making preforms used in the molding of plastics. At 50 strokes per minute, it applies, with every stroke, force generating pressures up to 15 tons! This part, machined from a piece of 3″ rd. 18″ long ELASTUF CHRO-MOLY Heat Treated, takes terrific punishment, and the manufacturer knows that this steel will give continuous and trouble-free service to the user. Why CHRO-MOLY? First, to ensure proper strength. Second, the part needs considerable machining, which is entirely possible with this steel in the heat-treated condition. Without this latter feature of CHRO-MOLY, the plunger would be difficult to manufacture, since it must be accurate, free from distortion and stress concentrations.

Perhaps this steel, which is providing the practical answer to so many problems, can be helpful to *you* right now.

Send for
"ELASTUF STEELS in ACTION"

This booklet describes many cases where CHRO-MOLY and other steels of the ELASTUF Group have made designs practical and established performance records. A copy is available to all department heads in Purchasing, Engineering and Plant Management. Address Machinery Steel Division at the nearest address below.

ELASTUF STEELS

BEALS-McCARTHY & ROGERS • **BUFFALO-ROCHESTER**
BROWN-WALES CO. • **BOSTON, MASS.-LEWISTON, ME.**
HORACE T. POTTS CO. • **PHILADELPHIA-BALTIMORE**

Heat Treating

THE A. F. HOLDEN COMPANY

Metallurgical Engineers

HEAT TREATING BATHS

NEW HAVEN, CONN.

Gentlemen:-

Defense Heat Treating demands speed, accuracy and uniformity. Applied metallurgical engineering and a new approach is essential to obtain these objectives.

During the past eight years developments in pot furnace designs and Salt Baths have made possible short cuts. These advancements are now available to maintain quality and speed production.

A recent application was the heating of bomb noses where cooperative engineering eliminated washing troubles and at the same time effected savings of 25% in consumed material.

Any one of our Metallurgical Engineers can advise you how to increase the life of your high speed tools, whether you make or purchase them. Increased high speed tool life by these newer methods average more than 75%.

Ceramic pots in our electrode furnaces are now guaranteed for six months when used at temperatures above 2000° F. and for one year at temperatures under 2000° F.

Regardless of the problem there is a short cut, which can be achieved with improved quality. Coordinated engineering in more than 1000 industrial plants makes this possible.

There is a Holden Engineer located near your plant for consultation. There are materials and equipment in operation which, without doubt, can be duplicated to meet your needs.

Very truly yours,

A. F. Holden

A. F. Holden

AFH/d

Extrusion of Light Alloys*

By R. Worsdale

FOR EXTRUSION of light alloys, horizontal hydraulic presses are the most satisfactory. Essentially, they consist of a container which receives the preheated ingot or billet to be extruded, the die, a pressure cylinder, and ram. The billet to be extruded is placed in the container, which is closed at one end by the die and at the other by a pad or pressure disk. This disk is moved by the pressure cylinder, through the ram; the metal is forced through the die, and takes the contour to which the die is cut. The flow through these presses, which vary in size from 250 to 6000 tons, can be regulated to very fine limits of speed, particularly necessary for extrusion of light alloys.

The container consists of a forged steel circular body lined with nickel-chromium-tungsten heat resisting steel and surrounded by a heating chamber. The ram, mounted in the pressure cylinder, moves horizontally. The die-head holds the die-plate, holder and bolster.

The die-plate, upon correct cutting of which depends the success of the extrusion, is a machined disk of nickel-chromium-tungsten steel on which is inscribed the contour of the section. The whole art of die making is in shaping the "bearing", or entrance contours, to insure an even flow of metal.

Die-plates for aluminum alloys are cut square, but for magnesium alloys a slight radius is necessary. All dies are relieved on the exit side, and highly polished. The die-holder and bolster are cut similarly to the die-plate, except the contour is larger.

Only the metal opposite the aperture flows straight through it, the rest passing to the rear and then down the center. "Coring" or "piping" from this complicated path must be avoided.

The billets are heated at 700 to 900° F., and soaked for 6 to 10 hr. Speed of the extrusion and the temperature of the metal are adjusted for each alloy. Hardeners in the alloys necessitate greater pressures.

Extruded parts are frequently quenched and aged. To minimize quenching distortion, vertical furnaces drop the load into a quenching bath below the furnace. Straightening is done by hydraulic stretching machines or by local "kinking".

*Abstracted from "Modern Practice and Developments in the Extrusion of High Strength Light Alloys", *Metallurgia*, February 1940, p. 117.

BARRELS, TABLES, SPECIAL CABINETS

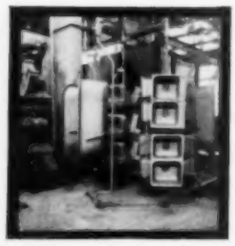
ROTOBLASTING *speeds work!*

No matter how tough the test—how difficult the problem—turn to Pangborn for blast cleaning that is QUICKER, CHEAPER and BETTER.

If pushed for production—install airless ROTOBLASTING—use it twenty-four hours a day—seven days a week. Pangborn Barrels, Tables and Special Cabinets have stamina and strength—have proven they can take it—BY CONTINUOUS INCREASED PRODUCTION.

For speed—for control—for lower cost cleaning—shift gears quickly into ROTOBLASTING. Costs have dropped as much as 50%. Production has increased as high as 80%. And quality goes up to the very top.

For quickest possible delivery—place tentative orders NOW.



WORLD'S LARGEST MANUFACTURER OF BLAST CLEANING & DUST CONTROL EQUIPMENT

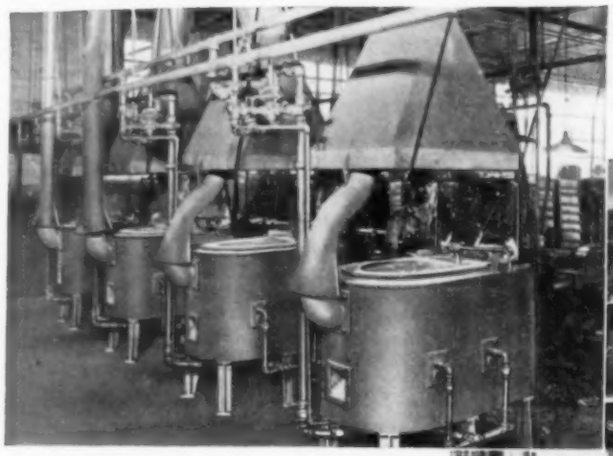
PANGBORN

PANGBORN CORPORATION · · · HAGERSTOWN, MD.

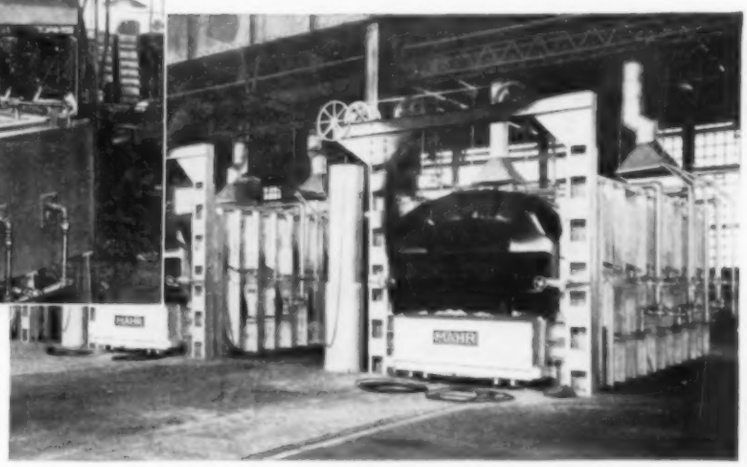
SMALLER POT FURNACES . . .

OR | *Large Installations for Hardening, Quenching and Drawing HIGH EXPLOSIVE SHELLS . . .*

MAHR MAKES 'EM ALL!



← LEFT: A battery of MAHR lead melting pot furnaces in use in a large battery plant. MAHR pot furnaces for melting or for heat treating with salt, cyanide etc. are fully described in Bulletin No. 110.



RIGHT: Part of a battery of large MAHR car bottom furnaces used in an important defense plant for carburizing armor plate. →

ASTONISHINGLY PROMPT DELIVERIES are being made on furnaces of all kinds, but plans for new equipment should be discussed now. Ask for special bulletins on any type of furnace you need, and let our engineers consult with you and offer their suggestions. WRITE TODAY!

● Yes, whether it's a preheating torch, a blacksmith or rivet forge, a pot furnace, a tool furnace or a complete high explosive shell hardening, quenching and drawing installation, MAHR engineers have made them all. No matter what your heat treating requirements may be, MAHR'S quarter of a century of experience in making all types of furnaces for all kinds of work is at your service. Today, when time is all-important — when the job must be done quickly and *right the first* time — place your confidence in this large and experienced organization.

DIAMAHR

MAHR MANUFACTURING CO.

DIVISION OF DIAMOND IRON WORKS, INC.

MINNEAPOLIS, MINNESOTA, U. S. A.

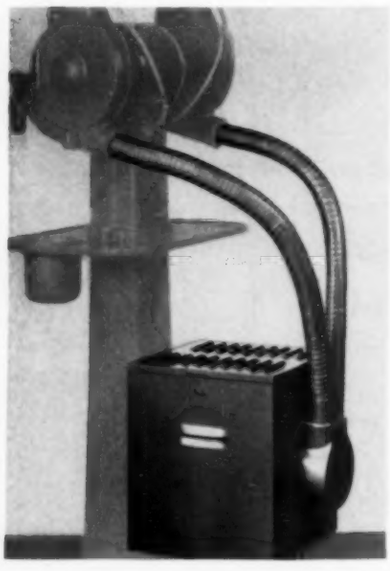
New Products Available

Marking Defense Parts

Pointing out that defense parts must be numbered and that wire, rods, strips and tubes have to be marked, this company announces the "Marking Roll and the Press Stamping Die". As parts are rolled or extruded, they pass underneath the marking roll, concaved on the face and engraved with raised lettering or numbering that impresses the mark. Diameter of the roll determines distance between marking intervals. The press stamping die is placed in the ram of a 10-ton or heavier punch press and a guide for positioning the part on the bed of the press completes the setup. By guiding the part so that the mark is stamped in the center of the most uniform flat surface, no damage to the parts results but a perfect mark is obtained, the manufacturer says. (No. 16)

Dust Arrestor

The view shows "Dustkop" mounted on a pedestal tool grinder. Described by the manufacturer as a device that arrests dust at its source, before it can do costly damage to equipment, spoil precision work and impair the usefulness of valuable operators. Dirt-laden air thrown off the grinder is pulled through the flexible hose into the two-way intake, and ejected through the louvered cover as clean, dust-free air. Delivery on high priority orders can be made in three weeks. Price, $95.00. (No. 17)



Magnetic Separator

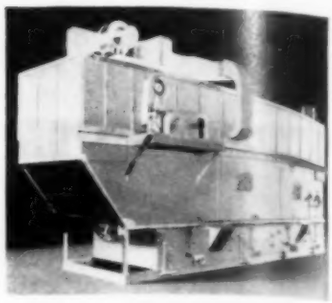
A permanently magnetic "Ferro-Filter" is described as adapted to the removal of harmful fine iron and steel particles from circulating coolant systems of machines used in tapping, grinding, deep hole drilling, reaming and rifling — also from circulating lubricating oil systems of pumps, blooming mill engines, rod mills, and roll grinders. (No. 18)

Rustproofing and Cleaning Solution

"Ruscat" is a new solution developed for cleaning metal surfaces before application of corrosion resistant coatings and also for preventing further rust formation. Is said to produce a mild etch over metal surfaces, and develop a chemically adherent inorganic base over which lacquers and coatings gain maximum adhesion. May be applied by brushing or dipping. (No. 19)

Processing Aluminum Alloys

This two-strand, cross-rod conveyorized processing machine is designed for cleaning and treatment of aluminum alloy sheets and parts according to U.S. Army and British specifications. Used in aircraft plants to make aluminum parts less pervious to effects of moist air, and to provide a better paint bond. Incorporates hot alkali wash, hot water rinse, hot chromic acid dip, hot water rinse, and oven dry-off. Oven is located over the top of the dip tanks, so that the conveyor and work pass through it on their return flight, thus eliminating rehandling of the



work. Another feature is that both steam and acid fumes are fully exhausted. (No. 20)

Remote Valve Control Unit

A newly designed unit for manual control of remote valves, dampers and other pneumatic equipment; said to hold pressures to narrow limits. Useful in other applications, such as setting control points of distant instruments, or positioning of pressure-producing pistons, located in inaccessible points. Operates over distances as great as 1,000 ft. (No. 21)

Hydraulic Testing Machine

Capacities up to 60,000 lb. for single or multi-purpose testing including tension, compression, transverse and Brinell hardness. Extensometer, specimen, load indicator and speed control scale can be observed from one position. (No. 22)

Oil Cooler

"Rapid Oil Coolers"; said to maintain a constant temperature in oil quenching baths, a necessity in producing uniform quality in heat treated metals. Designed in sizes to cover every capacity requirement. (No. 23)

Brazing Bombs

A high frequency brazing unit has been developed for brazing bomb parts in fixed position. After surfaces are prepared and a ring of compound placed, the

(Continued on page 404)

We will gladly pass on to the manufacturers requests for further information on products described here and on Page 404. Mention the paragraph numbers of the items in which you are interested.

Make NATIONAL Your SOURCE OF SUPPLY

FOR SAND AND PERMANENT MOLD *Aluminum* CASTINGS

★ Because this war must be won to save everything that United States of America represents, we, like many other manufacturers, will devote our entire production to war-time materials.

However, during this period National will endeavor to continue its pioneering, engineering, research and development. To our customers and to every one else using sand and permanent mold aluminum castings, we pledge to continue making our products in a manner that will justify their confidence. Our increased plant facilities will also enable us to give our customers better service and if humanly possible, better quality than ever before.

In times of war, prepare for peace ... plan now to make National your source of supply for sand and permanent mold aluminum castings.

THE NATIONAL BRONZE AND ALUMINUM FOUNDRY CO.

Twin Plants **Cleveland, Ohio**

NEW YORK, 111 Broadway • DETROIT, Stephenson Bldg. • CHICAGO, 188 W. Randolph • LOS ANGELES, 405 S. Hill

Sacrifice, Save, Serve

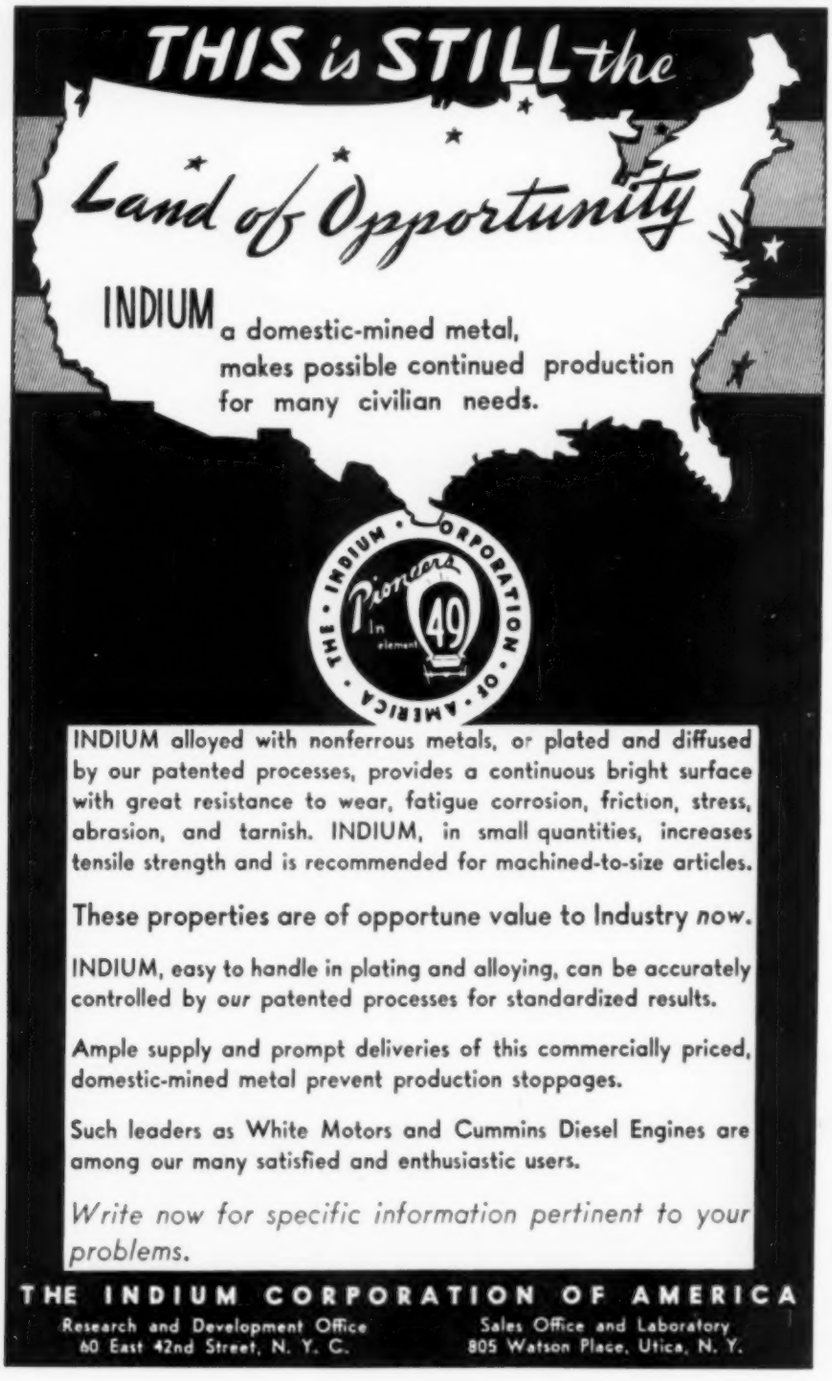
New Products

(Continued from page 402)

assembly is heated by placing it inside the induction ring. Parts are brazed together with no residue to clean up. Heat is localized — joint always the same — practically 100% perfect — time is one-third that required for welding, the manufacturer says. (No 24)

Humidity Control

"Kathabar" system of humidity control provides flexibility in operation with a dry blast of 1 grain per cu.ft. attainable, this manufacturer says. System has been developed for drying wind for the blast furnace or cupola, and for the laboratory atmosphere where operating conditions must be maintained at one level. Steps up production in blast furnace and foundry and increases quality of product. (No. 25)


THIS is STILL the
Land of Opportunity
INDIUM a domestic-mined metal, makes possible continued production for many civilian needs.
THE INDIUM CORPORATION OF AMERICA
Pioneers In element 49
INDIUM alloyed with nonferrous metals, or plated and diffused by our patented processes, provides a continuous bright surface with great resistance to wear, fatigue corrosion, friction, stress, abrasion, and tarnish. INDIUM, in small quantities, increases tensile strength and is recommended for machined-to-size articles.
These properties are of opportune value to Industry now.
INDIUM, easy to handle in plating and alloying, can be accurately controlled by our patented processes for standardized results.
Ample supply and prompt deliveries of this commercially priced, domestic-mined metal prevent production stoppages.
Such leaders as White Motors and Cummins Diesel Engines are among our many satisfied and enthusiastic users.
Write now for specific information pertinent to your problems.
THE INDIUM CORPORATION OF AMERICA
Research and Development Office
60 East 42nd Street, N. Y. C.
Sales Office and Laboratory
805 Watson Place, Utica, N. Y.

Industrial Brush

New type of tampico fiber industrial brush is expected to speed war production in aircraft, shipbuilding and other industries requiring brushing equipment to remove burrs or finish welded seams. Used with proper abrasives, brush will remove tool marks from aircraft motor parts, such as connecting rods, tappets, cams, etc. Used without abrasives, brush will remove burrs without damage from metals such as aluminum and Alclad. (No. 26)

Rust Prevention

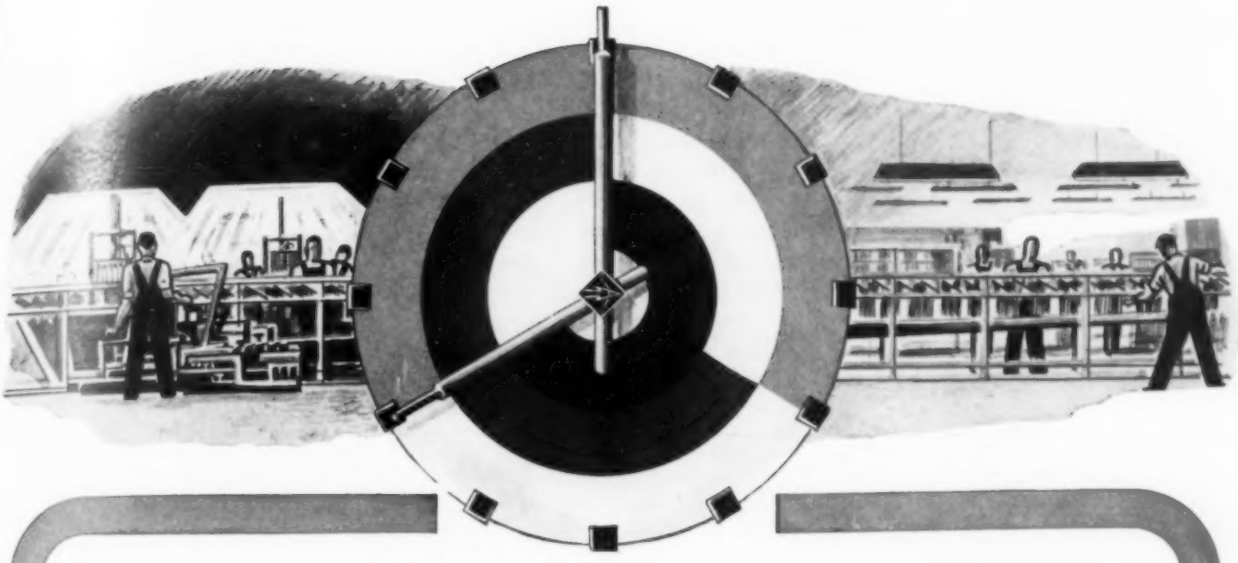
Pointing out that fingerprints may induce corrosion, this company offers "Ply-Rustex" cream which is applied to hands of workers before contact with highly polished metal surfaces. Eliminates perspiration corrosion and other forms of rusting. Such focal points of rust are said to be sealed in by ordinary rust preventives. (No. 27)

Peel Re-surfacing

Re-surfacing and maintenance of peels for charging steel scrap into openhearths — with "HCPF" welding electrodes — is said to produce from four to eight times longer service. Peels subjected to heavy abrasion can now be maintained with a monthly surfacing. Said to typify the many opportunities for improved welding due to the rapid advancement in electrode manufacture. (No. 28)

Saves Insulating Material

Improved design in method of insulating pots for electric salt bath furnaces has decreased amount of bricks required, reduced maintenance and increased the working space — as announced by manufacturers of "Electrothermic-Permeation" type of salt bath furnaces. Designed for low temperatures, and thus does not require brick insulation except at corners where electrodes are placed. When bricks are to be renewed, it is only necessary to slide them out at the top and replace them; moreover, the absence of bricks from the wall area adds valuable working space. (No. 29)



NIGHT AND DAY

Arcos Stainless Electrodes are being produced and are being used around the clock by the nation's welders. You can be sure, it's Arcos!

ARCOS CORPORATION
401 N. Broad St., Phila., Pa.

it's ARCOS for stainless electrodes

"QUALITY WELD METAL EASILY DEPOSITED"

Distributors Warehouse Stocks in the Following Cities:

ATLANTA, GA.	*J. M. Tull Metal & Supply Co.*
BUFFALO, N. Y.	*Root, Neal & Co.*
BORGER, TEXAS	*Hart Industrial Supply Co.*
BOSTON, MASS. (Belmont)	*H. Boker & Co., Inc.; W. E. Fluke*
CHICAGO, ILL.	*Machinery & Welder Corp.*
CINCINNATI, OHIO	*Williams & Co., Inc.*
CLEVELAND, OHIO	*Williams & Co., Inc.*
COLUMBUS, OHIO	*Williams & Co., Inc.*
DETROIT, MICHIGAN	*C. E. Phillips & Co., Inc.*
ERIE, PENNA.	*Boyd Welding Co.*
FT. WAYNE, IND.	*Wayne Welding Supply Co., Inc.*
HONOLULU, HAWAII	*Hawaiian Gas Products, Ltd.*
HOUSTON, TEXAS	*Champion Rivet Co. of Texas*
KANSAS CITY, MO.	*Welders Supply & Repair Co.*
KINGSPORT, TENN.	*Slip-Not Belting Corp.*
LOS ANGELES, CALIF.	*Ducommun Metals & Supply Co.*
MILWAUKEE, WIS.	*Machinery & Welder Corp.*
MOLINE, ILL.	*Machinery & Welder Corp.*
NEW YORK, N. Y.	*H. Boker & Co., Inc.*
OKLAHOMA CITY, OKLA.	*Hart Industrial Supply Co.*
PAMPA, TEXAS	*Hart Industrial Supply Co.*
PITTSBURGH, PA.	*Williams & Co., Inc.*
PORTLAND, OREGON	*Industrial Specialties Co.*
ROCHESTER, N. Y.	*Welding Supply Co.*
SAN FRANCISCO, CALIF.	*Ducommun Metals & Supply Co.*
SEATTLE, WASH.	*H. A. Cheever Co.*
ST. LOUIS, MO.	*Machinery & Welder Corp.*
SYRACUSE, N. Y.	*Welding Supply Co.*
TOLEDO, OHIO	*Williams & Co., Inc.*

Heavy Alloy

(Continued from page 337)

there is little tendency to sinter and consequently it does not matter if pieces are in contact with one another in the furnace. In the second stage of the firing a liquid phase is formed, and it is important that the briquettes should not be in contact with one another. During this second firing, a linear shrinkage of up to 20% occurs on all dimensions, and this must naturally be taken into consideration when designing the dies.

Heavy alloy thus prepared is entirely free from porosity and has the properties of alloys prepared by melting and casting.

It was found that for a given percentage of tungsten, the maximum density is obtained when the ratio of nickel to copper is about three to one; maximum tensile strength obtains when it is three or four to one. Alloys in which the copper exceeds nickel in amount do not sinter satisfactorily, and are likely to be porous. Alloys approach their theoretical densities more closely as the percentage of tungsten is reduced, but the theoretical values for density, at the same time, become less.

The optimum tungsten content is between 89 and 93%. If the combined nickel and copper additions exceed 10% the amount of liquid formed during sintering may be sufficient to cause the body to lose its shape. On the other hand, the sintering mechanism does not proceed within a reasonable time or at a practicable temperature if the nickel plus copper content is less than 5 or 6%. The best composition for production is close to 90% tungsten, 7.5% nickel, 2.5% copper, although this composition can hardly yet be taken as "standard".

The portion of the alloy which is liquid during sintering should not only wet the tungsten, but actually dissolve it. Therefore, the process is more rapid the greater the percentage of fine particles, and the sintering temperature is lower the finer the tungsten powder.

The higher the compacting pressure the smaller will be the shrinkage, but the final density will not be appreciably affected. For normal purposes a pressure of 5 tons per sq.in. is adopted, the percentage shrinkage in this case being 17 to 17.5%.

There is a critical sintering temperature corresponding to the appearance of a liquid phase, thus depending on the composition of the alloy. A very rapid change in density occurs in the hot compact between 2650 and 2750° F., and sintering should be carried out as near to the critical temperature as possible.

(Continued on page 411)

IT'S MADE OUT OF
SPEED CASE STEEL
A LOW CARBON OPEN HEARTH PRODUCT

–because . . .

It increased production 42%!
It saved $29.64 per ton used
It reduced warpage 75%
It carburized without soft spots

Ductility Plus Machinability (230 SFPM)

THANK YOU! *To friends both old and new . . . thanks for your patience. We are doing our very best for Defense . . . and also for you.*

Licensor
MONARCH STEEL COMPANY
HAMMOND • INDIANAPOLIS • CHICAGO
PECKOVER'S LTD., Toronto, Canadian Distributor

Licensee for Eastern States
THE FITZSIMONS COMPANY
YOUNGSTOWN, OHIO

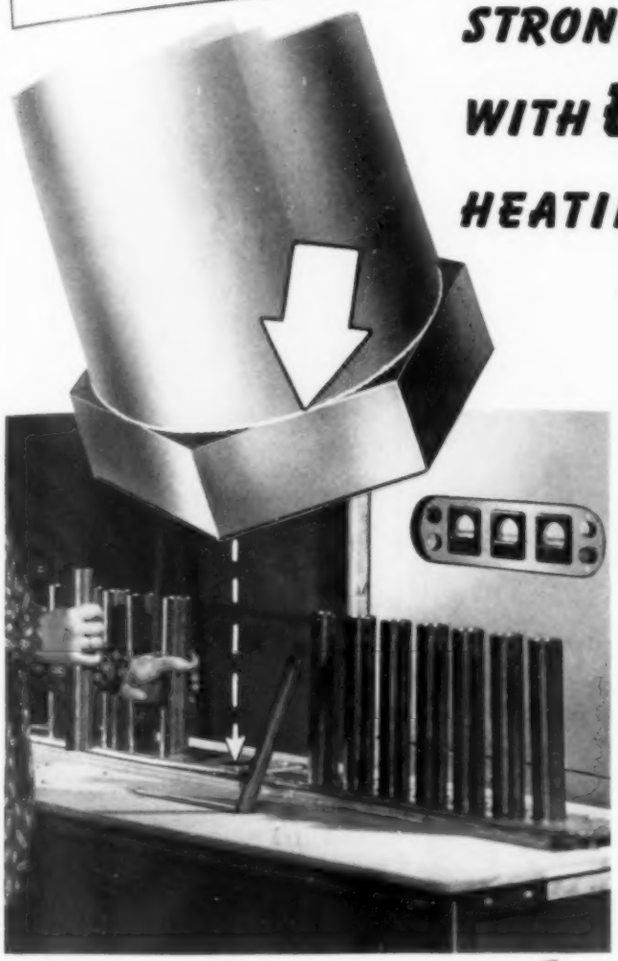
MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

Another

FROM THE THOUSANDS OF VICTORY PRODUCTION JOBS BEING BRAZED WITH . . .

EASY-FLO

STRONG JOINTS—120 PER HOUR WITH EASY-FLO PLUS A FAST HEATING PROCEDURE!



This job is another example of the high production metal joining that can be obtained by the fast action of EASY-FLO brazing alloy plus a procedure designed to facilitate handling and give fast heating.

THE JOB — Joining the steel nosepiece to a steel shell.

PROCEDURE — After fluxing, *a ring of EASY-FLO is preplaced* in a groove in the nosepieces which are then assembled in the shells. Next the assemblies are placed, 7 at a time as shown at the left, in the hexagonal shaped holes in the coil fixture of an induction heating unit. The switch lever is thrown and in a matter of seconds the 7 joints are made — joints that meet all physical requirements.

One feature of EASY-FLO is that *thin films make the strongest joints.* This cuts down the amount of alloy needed. On the job illustrated, it takes only 40 ounces of 3/64" of EASY-FLO wire to make 1000 joints. Preplacing the alloy gives accurate control of the amount of alloy used.

✻ REASONS WHY EASY-FLO MAKES STRONG, SOUND JOINTS IN QUICK TIME . . .

Free-flowing to an exceptional degree, EASY-FLO penetrates, the instant its flow point is reached, to all parts of a joint and *into* the surfaces of the metals, actually alloying with them. Add to this fast and complete penetration the low working temperature of EASY-FLO—1175 F.—and you have the answer to EASY-FLO brazing: SPEED plus RELIABILITY. Complete details are given in Bulletin No. 12.

MAYBE WE CAN HELP YOU SPEED UP YOUR BRAZING . . .

If you can use increased production — or better joints — on any ferrous, non-ferrous or dissimilar metal joining job, we'll be glad to send a Field Engineer to show you what EASY-FLO can do and help work out the most effective handling and heating procedure for the job.

For complete EASY-FLO details, write for Bulletin No. 12.

HANDY & HARMAN 82 FULTON ST., NEW YORK

Agents in Principal Cities. In Canada: HANDY & HARMAN of Canada, Ltd., Toronto

Heavy Alloy

(Starts on page 337)

Microstructural changes occurring during sintering indicate that between 1800 and 2000° F. the nickel and copper particles become alloyed by diffusion, and cohere slightly to the tungsten grains. Above the melting point of the nickel-copper alloy the tungsten particles are rapidly dissolved by the liquid phase, but tungsten is re-precipitated on certain nuclei and develops into the characteristic large, rounded grains. This process continues until all the original fine tungsten particles are replaced by fairly uniform grains with diameters about 100 times those of the original particles.

The more important physical properties of heavy alloy are:

Properties of Heavy Alloy
90% W, 7.5% Ni, 2.5% Cu

Tensile strength	90,000 psi.
Yield point	83,000 psi.
Elongation in 1 in.	4%
Elastic modulus	32×10^6 psi.
Brinell hardness	250 to 290
Specific gravity	16.3 to 17.0 g. per
Weight	0.6 lb. per cu. in.
Coefficient of expansion	5.6×10^{-6}
Thermal conductivity	0.25 c.g.s. units
Specific resistance	1.16×10^{-5} ohm

Heavy alloy is very resistant to atmospheric corrosion and has good machining properties. It may be plated with any of the usual finishes such as nickel, cadmium or chromium. The strength of heavy alloy, of any particular composition, is a function of the density and therefore it will increase as the sintering proceeds.

Heavy alloy may be brazed or silver soldered to other metals using the ordinary fluxes, and hydrogen welding is able to join pieces together.

Heavy alloy was developed originally for the container and nozzle of radium units. It is now used for screens in X-ray tubes, for cosmic ray absorption measurements, for the construction of surface applicators in radium treatment, and as a screening material in research work on radioactivity and radiographic examination of materials. Other more "practical" uses, in addition to the "scientific", cluster about its utility as contact surfaces of electrical circuit breakers. A layer ¼ in. thick was found to be sufficient to limit the burning to a tolerable degree.

Probably its major application is for mass balancing of high speed machinery. A rotating piece of heavy alloy is capable of storing twice as much energy as a piece of steel of the same size, and it has much greater strength and heat resistance than lead. Alloy of the 90% W, 7.5% Ni, 2.5% Cu type is therefore very suitable for gas engine work.

Specify
R-S FURNACES
A PLEDGE AND A PROMISE
Designers and manufacturers of a diversified line of heat-treating furnaces since 1908, R-S pledges full support of the all-out production effort so that Democracy and our free way of life may survive. Now is the time when specialized experience and speed can best serve the common goal of supremacy over aggression.
Steel and other metals for the implements of war must be heat-treated. R-S Engineers are specialists in the manufacture of heat-treating furnaces — furnaces that are designed for every heat-treating operation and for uniform, peak production. Previously arranged plans permit of surprisingly fast deliveries.
For the speedy solution of emergency heat-treating problems, R-S promises full cooperation for the duration.
Call on experienced R-S Engineers.
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Tulsa, Oklahoma
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FIELDS IN WHICH STEEL CASTINGS ARE CONSTANTLY USED

Aeronautical
Agricultural Machinery
Automotive
Bearing
Boiler, Tank & Piping
Bridge
Chemical & Paint Works
Compressors (Pneumatic)
Conveyor & Material Handling
Crushing Machinery & Cement Mill
Dredge
Electrical Machinery & Equipment
Elevator
Engine
Food Processing & Packing Plant
Foundry Machinery & Equipment
Gas Producer & Coke Oven
Gears
Heat Treating Furnace & Equipment
Hoist & Derrick
Iron & Steel Industries
Metallurgical Machinery
Mining Machinery & Equipment
Oil or Gas Field & Refinery
Ordnance
Overhead Crane & Charging Machine
Paper Mill
Printing Press
Pump
Railroad
Refractory, Brickyard & Ceramic
Refrigeration Machinery
Road & Building Construction
Rubber Mill
Ship & Marine
Shoe Machinery
Smelting Plant
Spray Painting Equipment
Steam Turbine
Street, Elevated, & Subway Cars
Textile Machinery
Valves, Fittings & Piping
Well Drilling Equipment

Notes About Contributors

C. F. Nagel, Jr., who shows on page 323 how the vague inspection standards now in use are hampering aircraft production, has spent his entire metallurgical career in the Aluminum Co. of America. He is chief metallurgist of the fabricating division at the present time, a job he has held since 1928. Mr. Nagel is a graduate of Cornell University where he received his Bachelor of Arts degree in 1914 and Bachelor of Chemistry in 1915. His first position in the Aluminum Co. was that of assistant to the chief chemist. He was later placed in charge of the products and process division of the technical department and in 1923 was made assistant technical director. Upon reorganization of the company's technical department, he was placed in charge of the newly formed fabricating department. Here he has spent a great deal of his time in studying the adaptability of aluminum and aluminum alloys to aircraft.

Norman Fenwick Tisdale, a native of Canada, entered Queens University, Kingston, Ont., but before completing his course, took time out for service in the first World War. He returned to Canada in 1919 and graduated as Bachelor of Science in chemical and metallurgical engineering. Since then he has been employed as research metallurgist on cobalt for the M. J. O'Brien Co., metallurgist for General Motors, Rolls Royce Automobile Co., and Lincoln Automobile. Later he was employed as a metallurgical engineer for Halcomb Steel Co., Ladish Drop Forge Co., Union Electric Steel Co., Republic Steel Corp., Titanium Alloy Mfg. Co., and for the past seven years as metallurgical engineer for Molybdenum Corp. of America. He is now a member of the Board of Trustees.

One of the best known authorities in the country on copper alloys and all phases of their production, treatment, testing and uses, **D. K. Crampton** has been employed continuously by Chase Brass and Copper Co. since 1916. He served first as assistant metallurgist, was chief metallurgist from 1921 to 1924, and has been since then director of research. He is a New Englander by birth as well as education, having attended the New Haven public schools and Yale University, where he received a Ph.B. in 1916, M.S. in 1918, and Ph.D. in 1932. He has served one term on the Advisory Board of METAL PROGRESS, and is currently Chairman of the Institute of Metals Division of the American Institute of Mining & Metallurgical Engineers.

P. H. Brace was born in Leavenworth, Kansas in 1890 but moved to Denver at an early age. His father was a mining engineer so he learned a great deal about metals and their application at home. However, his degree (University of Colorado, 1912) was in electrical engineering. After graduation he enrolled in the Westinghouse student training course and became interested in research. He was one of the original members of the Westinghouse Research Laboratories, where his work has involved intent study of special metals for the electrical industry. At present he is consulting metallurgist in the laboratories.

P. H. BRACE

C. F. NAGEL, JR.

NORMAN F. TISDALE

D. K. CRAMPTON

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

ALVAN T. SIMONDS

IT is spring weather in Boston. Put- a light top-coat for the first time since hands, thrust into the pockets, en- papers. Some were clippings of the of Alvan Simonds, which I had with me to Fitchburg when acting as pall bearer at my old friend's on September 4th. He Guy, that man, with a silver spoon in his mouth," he into service for twelve, and then Graduated from Harvard, he studied at Sheffield, England, learned the of tool making and blacksmithing hammer and forge. Alvan carried a "iron handshake" through life, be- a rare vitality, second only to his curiosity. He was a Captain in the Army in the last war. He worked, to find what made all things and had passed from mechanics into when he put Adolf Hitler under scope. He and I discussed Germany comparing our own notes on the from the record, and we were in in the early nineteen-thirties THAT Germans must be annihilated finally peace in the world, THE SOONER CHEAPER." He published reams of U. S." material, was castigated as a Here's a sample of CLEAR to the everlasting credit of Alvan late president of the Simonds Steel Company:

AT do you think the Germans would to France and Italy if they had won World War? What did they do to Belgium French territory which they did over- the mines, the Louvain library, the the Cathedral of Rheims and the What they will do if they ever win war, we can judge by what they did to soldiers and leaders in the *"Purge"* what they have done and are doing to

are defeated in another great war, Carthaginians they will, I believe, dis- from the pages of history. If they win, bring Heaven on earth but Hell. that, in 1918, we did not do unto them would do unto us. By us, I mean the honorable nations of the world. Re- the Lusitania when next you plan a

ARDLESS of the contracts, why should arm, and arm, and arm, and keep rapid armament race, because surely can afford and will put into the field as many airplanes as the next nation do. And why not?

WARS the so-called civilized world ought again for Germany to attack. If must be annihilated finally to have in the world, the sooner the cheaper; all Americans remember not that "blood wipes out the ink" but that "the pen is mightier than the sword." Let them remember that individual freedom of speech, freedom of worship and freedom to vote for leaders according to their own individual choice are without price, and neither gold nor raw material nor territory will ever be of any use as a source of happiness for the people unless these conditions accompany them.

SO, America, get ready for the next war and do not delay. Learn from the sacrifices of the past that no matter what America wishes, she cannot keep out of the next world war. Certainly if Germany and Italy and Japan want an armament race, want plans laid for poison gases and pollution of water supplies, let them remember that America cannot be left out of the calculation and that America will always take sides first with those who have the greater morality, the greater humanity, and against those who believe in calling contracts "Scraps of Paper" and that "Blood wipes out the ink."

ALVAN T. SIMONDS.

Fitchburg, Mass., May 18, 1936.

A NEW VOICE

A NEW VOICE will soon be heard in the land. A stronger voice than the voice of Labor or Capital, with a truer ring. This voice will resound in the hearts of men and the marts of trade. It will echo in every workshop and every chartroom of industry. It will blast the yellow streaks in our flame of patriotism to blue and the blue to incandescence. This voice is the VOICE OF AMERICAN DEAD FROM THE FIELD OF BATTLE. It will swell to a mighty chorus before VICTORY IS OURS.

OF each and every one of us let it be said that with our fighting forces we have kept faith.

POODLE WOOL! In the last war we kept a few hundred head of angora goats on our Champaign County, Ill., farms. The best wool bearers were selected for shearing, and the wool was specially spun into yarn dyed khaki, and shipped with our compliments to Mrs. Theodore Roosevelt at Oyster Harbor. This Gracious Lady supervised the knitting of many "T.R. Angora" sweaters for our Soldiers in France, where they became prized possessions. In fact, it is rumored that Charles MacArthur, playwright, who later married Helen Hayes, traded three M'lles and a Primus stove for one.

RUPERT THE "POOD"

BETWEEN wars people got every goat we had, but beginning with Pearl Harbor we began shearing Rupert, our French Poodle, whose hair is to goat wool like Q-Alloy to a steel foundry hi-carbon copy. When we went to put the last shearing in the bag out flew a squadron of saboteur moths so laden they could just make nine inches of altitude. We had planned to send that Poodle wool to Mrs. Franklin D. Roosevelt. Rupert is growing a new crop, and if all goes well some Jap-Smasher will have a crop of brown down on his chest that he'll have to comb the Gidgies out of with a bayonet.

NEW PROCESS FOR VICTORY

THE above castings are part of an assembly for one of the several new processes pointing the wedge to Nazi defeat through better tools for fighting men.

NOTHING so clearly illustrates the difference between General Alloys as an engineering organization and the horde of steel foundries who make alloy castings as the engineering development problems and alloy mechanism that we are doing—both alloy engineering and process engineering involving alloy mechanism, as well as developing new types of foundry practice to meet unusual needs in the VICTORY program.

THE real way to save nickel and chrome for Defense is through lighter sections, better design and the elimination of alloy abuse. Stop using trays as ramrods—stop building dumb stuff out of alloy that just sits and grunts when the same weight of alloy could go to work and speed Defense production.

PROPER application of alloy is an engineering job. You can count the alloy engineers of America on a crippled hand. General Alloys' experience, facilities and organization are still open for more VICTORY process and product developments.

GOSH, how the air improves heading out of Washington, D. C. D. C. Cabbies are cynics. "Them Natzeys ain't agoin' to mob Washington," says one. "They're too smart to lift the U. S. Handicap". Most Cab Drivers were worrying about tires, but not Pete from Baltimore who just bought a D. C. cab. "These Pols are going to have cushions under their tails and roll on rubber even if the rest of the country walks." "Most of these birds came down here by suckin' and stayed here by blowin'" continues Pete. Joe is a colored rubber in Rigg's Turkish Bath who meets "Statesmen" en repose. "Mosta de gemmun is a-drinkin' straincure outa de bottle. Holdin' onta de labor vote wit dere two hans an' wavin' de flag has got 'em plumb tukkered out" opines Joe. The finishing touch on Washington is supplied by our old friend Harry McQuaid—"Somebody circulated a phony password around here last week, 'SNEFU'. We've been trying to de-code it and have so far doped the first two letters as 'Situation Normal'."

SERIOUSLY, Washington would be a far worse place if there were not so many sincere competent people working their heads off, and doing a darn-creditable job of constructive RESULT GETTING. Many, Many "Impossible" jobs are rolling off the line. Over one able Officer's desk hangs a sign "The Difficult we do IMMEDIATELY. The IMPOSSIBLE takes just a little bit longer." THAT SIGN IS NO JOKE. When we catch up with those Japs, they'll think the cat that swallowed the quart of castor oil was only having "The Pause that Refreshes."

H. L. Harris

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY
GA X-ITE GA X-ITE GA Q-ALLOYS GA Q-ALLOYS

Surface Quality

(Continued from page 329)

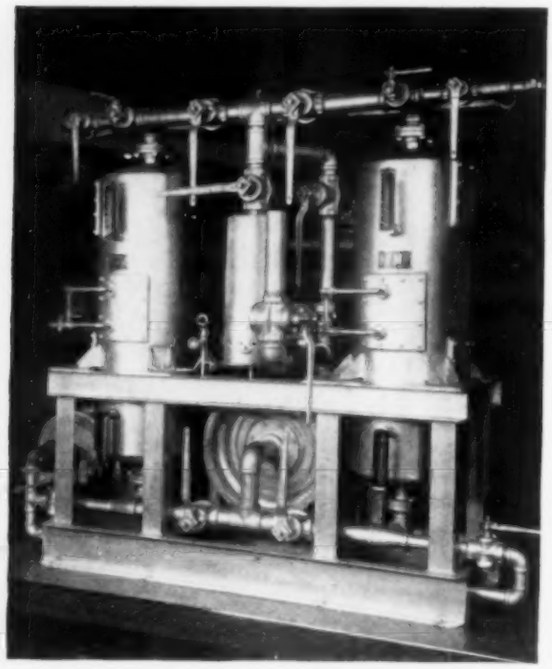
as a column. However, when the lack of straightness is so slight that the section can be caused to touch all portions of a flat surface upon the slight pressure exerted by one's finger, and when the shape is so fastened in the completed structure that any original bow is obliterated, then the author believes that such material is perfectly satisfactory. Moreover, the smaller, lighter sections are never employed as long columns, but it is just with these smaller sections that the greatest expense is incurred in meeting current straightness requirements. Many of these extruded shapes are later cut up into rather short lengths, although the straightness requirement is applied on the entire piece.

The space allotted this paper is only sufficient to present this whole complicated situation in a rather sketchy manner. It might not be amiss to add that the author, during the past three years, has discussed this subject with many people — both in governmental and commercial aviation — and, without exception, their belief has been that it is a very important situation, one that vitally affects speed of production. Everyone admits that something should be done, but no one can answer the question, "Who shall do what?"

A couple of years ago my recommendation would have been that a qualified group should be appointed, sponsored by some neutral agency, authorized to plan a test program, gather the data, and reduce the results to some form that may be expressed in a specification in terms understandable to inspectors, free of ambiguity. Such a program should precede any change in specifications.

I fear the time is not now available to proceed in that manner. We now need immediate action and results.

Many of the quality questions raised in this article can undoubtedly be answered quite reliably by individuals who know what these requirements mean in terms of production of extrusions, sheets, and forgings, who know what these requirements mean in terms of fabrication into completed air frames, and who know how these quality matters have affected the performance of aircraft in the air. In the present situation, such joint action must be taken under the sponsorship of some governmental agency, such as the group responsible for the Army-Navy aeronautical standards. The situation was serious enough a couple of years ago when the aircraft program was just getting under way. It has now become vastly more serious, when every effort must be strained for more planes.



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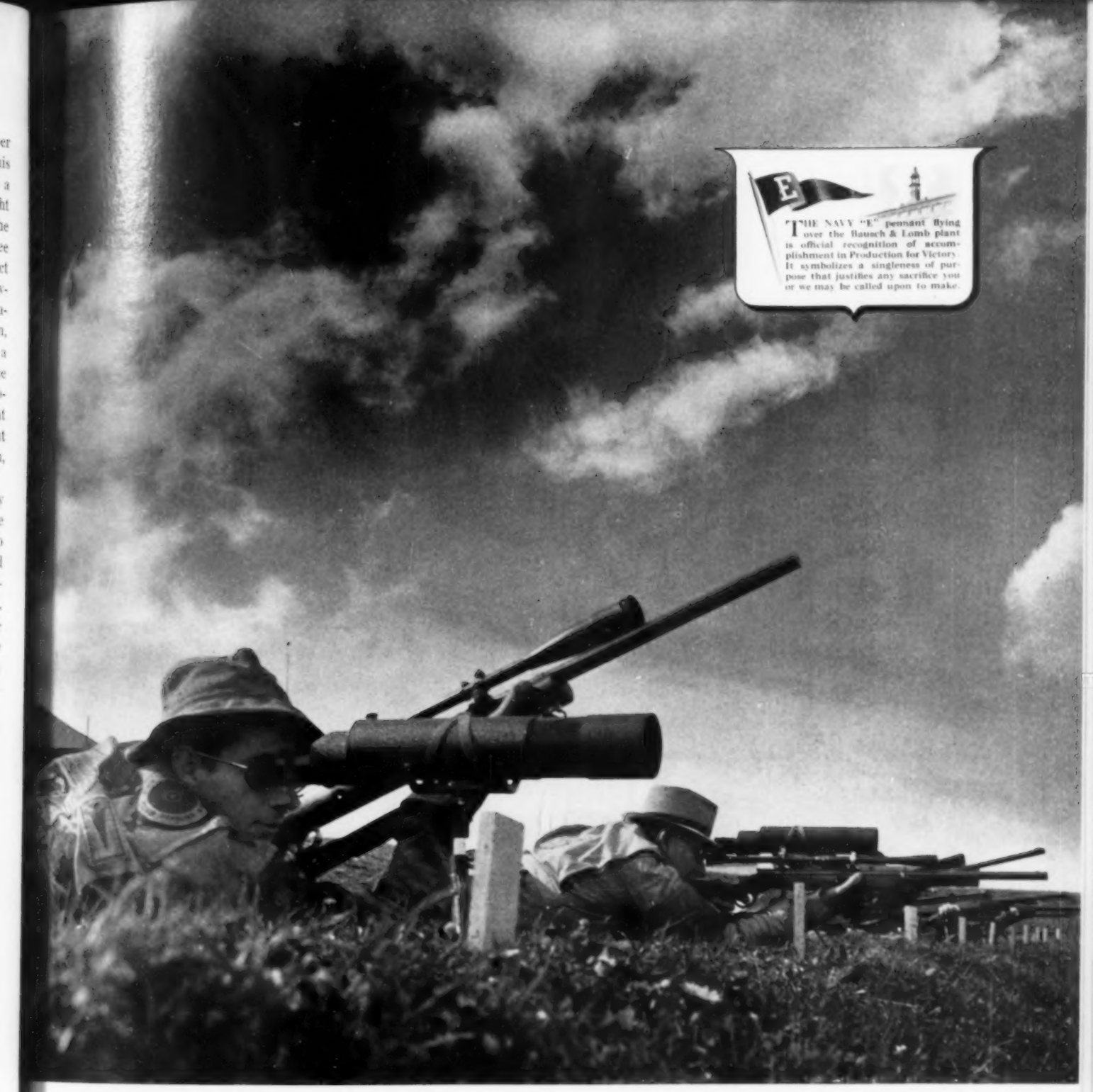
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THE NAVY "E" pennant flying over the Bausch & Lomb plant is official recognition of accomplishment in Production for Victory. It symbolizes a singleness of purpose that justifies any sacrifice you or we may be called upon to make.

Heritage From Saratoga

OF all they faced that day at Saratoga, Burgoyne's Redcoats remembered longest the withering accuracy of Morgan's Virginia riflemen. So it was at the Cowpens. Later, at New Orleans, the deadliness of Kentucky sharpshooters moved Napoleon himself, when he heard of it, to write that it had changed the face of war. And all down the years through the Argonne, America's opponents learned a healthy respect for the armies of a nation of riflemen.

That skill was no accident. The colonists shot for prizes. The pioneers practiced for their lives. Generation after generation, Americans grew up with the rifle. "Shooting at a mark" for sport has been a great foundation of American readiness for defense.

Today, on hundreds of ranges across the nation, shooters strive to attain the skill that groups shots in a smaller and smaller circle. At their matches, you'll see a predominant use of Bausch & Lomb products. Ray-Ban Shooting Glasses, the safe, scientific glare protection. Spotting Scopes, with which the shooter spots his shots and dopes wind conditions and "mirage."

And the marksmanship that makes American naval gunners the most accurate in the world is due in no small measure to the excellence of optical gunfire control equipment—range finders, binoculars, aerial height finders—produced by Bausch & Lomb.

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Electron Microscopes*

THE MICROSCOPE has played an important part in scientific discoveries but it is being surpassed today by a new type of magnifying instrument known as the electron microscope, which is extending the range of useful magnification far beyond its old limits. The discovery that beams of electrons could be focused by magnetic or by electric fields and the demonstration of their wave nature led to the development of the electron microscope. Useful magnifications of almost a million fold have been obtained. In both optical and electron microscopes the corpuscles (light waves or electrons) coming from the object are focused upon an image plane to form a magnified image of the object. They differ in the method of focusing, the manner of observing the image, the way in which the details of the object are distinguished, and the sources of illumination.

Electron microscopes are focused either by magnetic "lenses" (permanent magnets or electromagnets), or electrostatic "lenses" (charged plates or co-axial cylinders) in which the magnetic or electric fields have a high degree of symmetry about one axis, so that all electrons coming from a point on the object will again be brought together at a single point in the image plane. Focusing is done by controlling the potential of one of the plates or by changing the current in one of the electromagnets. To get high magnifications the distance object lens must be small while the distance of lens to image must be large.

Certain simple forms of electron microscopes do not employ lenses. In these the image is formed by a radial projection of electrons from the object.

By placing a fluorescent screen at the image plane, the electron image becomes visible. The pattern can be recorded either by photographing the image on the fluorescent screen or by placing a photographic plate directly in the image plane.

Turning now to the nature of the object being examined, there are electron microscopes in which the electrons pass through a thin object, others where the electrons are reflected from a thick object, and still a third where they come directly from an object which emits electrons.

(Continued on page 434)

*"Electron Microscopes and Their Uses", by Joseph A. Becker and Arthur J. Ahearn, *The Scientific Monthly*, Vol. 53, October 1941, p. 309, and "Electron Diffraction Studies of Thin Films. II. Anomalous Powder Patterns Produced by Small Crystals", by L. H. Germer and Addison H. White, *The Physical Review*, Vol. 60, Sept. 15, 1941, p. 447.

Typical parts made of Ampco Metal shown at right.

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Electron Microscope

(Continued from page 430)

In the simplest electron microscope the object, in the form of a fine filament, is placed in the axis of an evacuated glass tube, the inner surface of which is coated with a fluorescent screen. The anode consists of a cylindrical spiral of wire in contact with the screen. When the filament is heated and a potential difference of a few thousand volts applied between filament and anode, the thermionic electrons travel radially from the filament toward the screen.

In the Müeller electron microscope the cathode consists of a small wire whose end has been etched to a fine point. This "point" is mounted at the center of a spherical glass bulb whose inner surface is coated with fluorescent material. When a potential of a few thousand volts is applied to the screen, electrons are emitted and travel radially to the screen. Magnifications of half a million or more can be so obtained.

The Davisson-Calbick microscope employs electrostatic lenses. The object, a narrow ribbon of metal, when heated, emits thermionic electrons. Some of these pass through the small holes in the lenses and are focused onto the fluorescent screen. Magnifications of 50 to 500 are easily obtained.

The "super-microscope", employing transmitted electrons and magnetic lenses, is used to see very thin objects through which a stream of electrons is projected. A beam of electrons at about 50 kilovolts strikes the specimen, which has been placed near the objective lens. Different regions of the specimen absorb or scatter electrons in varying amounts. The electrons passing through the specimen form a density pattern which the objective lens focuses into an intermediate image. This image is magnified by the projector lens, and the final image is formed near the base of the microscope. Useful magnifications as high as 100,000 diameters have already been obtained with this microscope and points on the object separated by only a millionth of a centimeter have been resolved. Objects are usually mounted on thin sheets of nitro-cellulose. Delicate objects are easily damaged by the intense electron beam. Special techniques have been developed for mounting specimens and inserting them into the highly evacuated chamber. A recently developed form of this microscope has a light microscope built into it for simultaneous observation.

In another type of microscope infra-red rays that have passed through or have been reflected by an object are projected onto a surface which emits electrons when it is so illuminated. The emitted electrons are then focused on a fluorescent screen.

(Continued on page 438)

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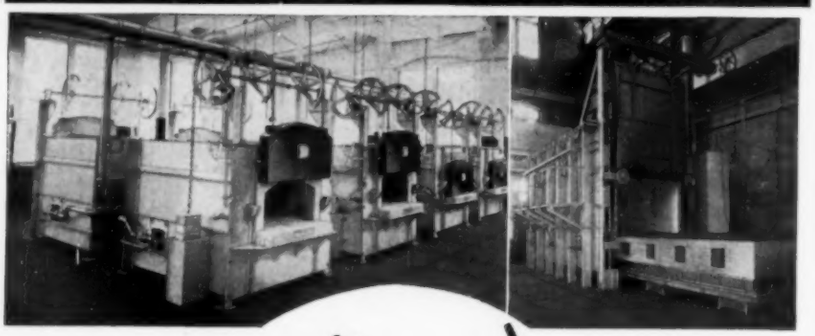

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of Artillery Shell Cases

The accompanying illustration shows a design to solve the problem of annealing and acid pickling artillery shell cases worked out by Driver-Harris Co. This fixture is made of Nichrome and Chromax, the two *allies* in alloys that suitably withstand both the annealing temperature and the pickling.

The construction involves three baskets removable from the center post. These can be loaded separately and after loading placed on the center post. The design provides means of handling the assembly at either or both ends of the post so as to drain the shells of the pickling solution. Wire mesh liners are attached to each cast spider.

These assemblies loaded are placed in vertical radiant tube furnaces with forced circulation.

Just another heat resisting problem solved by Driver-Harris engineers.

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and

NICHROME*

The Allies in Alloys

Made Only by

DRIVER-HARRIS COMPANY

Harrison New Jersey

Chromax castings combined with Nichrome Sheet

*Trade Mark Reg. U. S. Pat. Off.

Electron Microscope

(Continued from page 434)

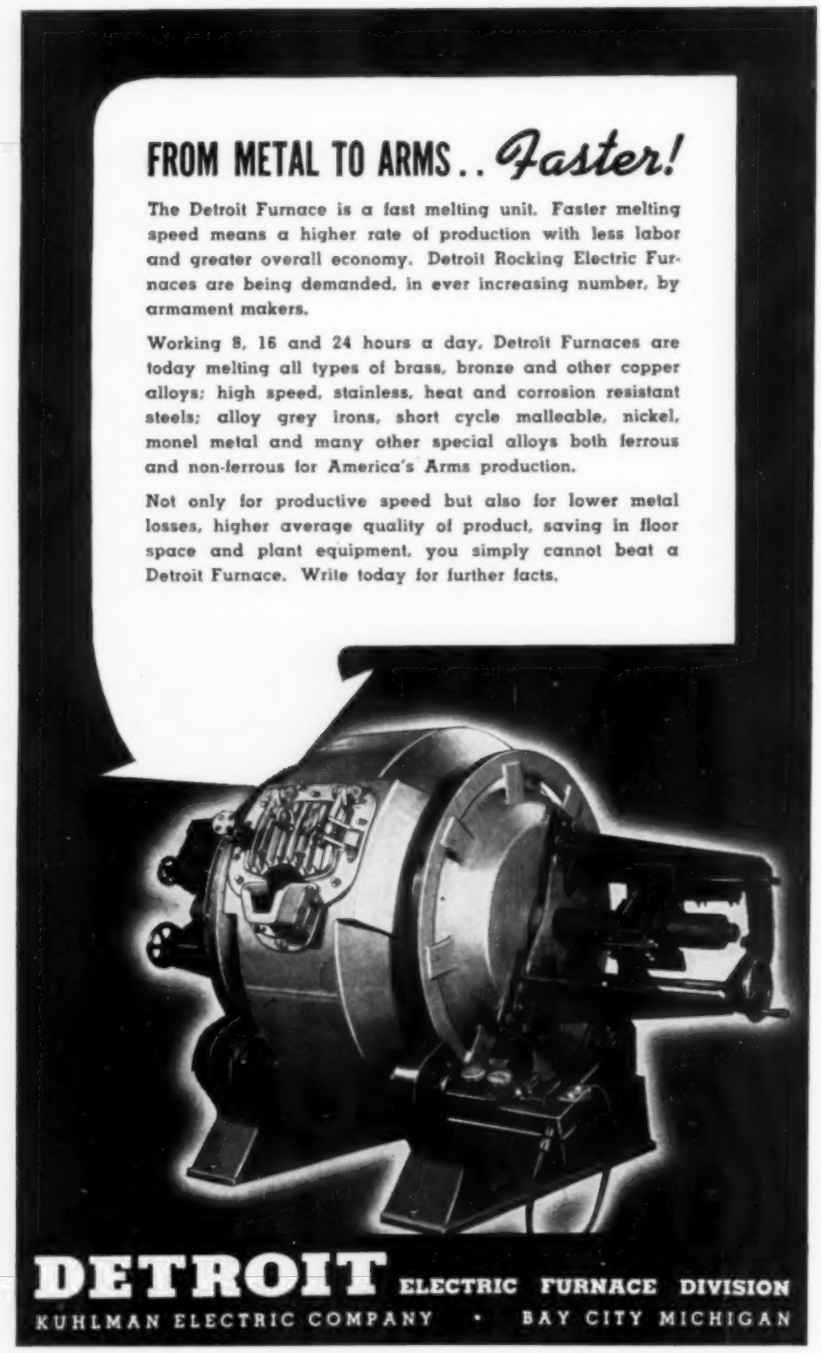
When secondary electrons are used, the object is bombarded by primary electrons.

One of the earliest uses of the electron microscope was the study of thermionic emission, particularly the emission from thoriated tungsten, and it has been shown how thorium diffuses to the tungsten surface, how it migrates and evaporates, and how the tungsten's structure influences these processes.

The spherical microscope has been used successfully to study tungsten surfaces on which barium has been deposited, and to study the adsorption of oxygen. It has been demonstrated that the barium is not rigidly anchored to the tungsten but begins to migrate at about 1150° F., and that adsorbed oxygen hampers thermionic emission.

The difference in the electron emission from different crystal faces of the same metal has made the electron microscope particularly useful in studying grain growth and crystal transformations. The transmitted-electron type of microscope has revealed several important facts, such as that the silver grains in a photographic film resemble loose balls of thread, that very minute particles in fine powders have the same crystal structure as the corresponding large particles, and that the size and shape of colloidal carbon particles is smaller than that revealed by earlier techniques. In biological fields, many interesting details have also been revealed.

As an instance of a metallurgical application it may be noted that some thin films of copper diffract electron patterns in which the relative intensities of the rings in the image are quite abnormal. It has always seemed certain that this is caused by extremely small individual crystals; in exceptional cases the qualitative term "partly amorphous" has even been applied. For instance the ring in the pattern emanating from the (200) plane of atoms is relatively very weak in electron diffraction patterns produced by small crystals of face-centered cubic type. To study this anomaly microphotometer curves were obtained from copper films in which the mean linear dimensions of the crystals varied from 20 to 67 Ångström units. The ratio of intensities of the (200) and (111) rings was determined, and found to vary from 0.14 for the 20-Å crystals to 0.42 for the 67-Å crystals. (This corresponds to the theoretical ratio for "coarse" grains, in the practical sense.) After the usual corrections were made for the scattering effect from gas molecules which may have been present, it would appear that the very smallest crystals contained somewhere between 55 and 379 atoms each, a somewhat smaller size than that previously estimated.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